

Extinction Can Reduce the Impact of Reward Cues on Reward-Seeking Behavior

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Reward-associated cues are thought to promote relapse after treatment of appetitive disorders such as drug-taking, binge eating, and gambling. This process has been modelled in the laboratory using a Pavlovian-instrumental transfer (PIT) design in which Pavlovian cues facilitate instrumental reward-directed action. Attempts to reduce facilitation by cue exposure (extinction) have produced mixed results. We tested the effect of extinction in a recently developed PIT procedure using a natural reward, chocolate, in human participants. Facilitation of instrumental responding was only observed in participants who were aware of the Pavlovian contingencies. Pavlovian extinction successfully reduced, but did not completely eliminate, expectancy of reward and facilitation of instrumental responding. The results indicate that exposure can reduce the ability of cues to promote reward-directed behavior in the laboratory. However, the residual potency of extinguished cues means that additional active strategies may be needed in clinical practice to train patients to resist the impact of these cues in their environment.

Keywords: extinction; reward; Pavlovian instrumental transfer; addiction; expectancy

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THERE IS GOOD EVIDENCE that reward cues can modulate behavior directed towards obtaining that reward, both for natural rewards such as food and manmade rewards such as addictive drugs. For example, patients who return to drug use after abstinence often report that their relapse was precipitated by exposure to reward cues. These cues might include visual or olfactory stimuli, places, time of day or mood states, or a complex combination, such as attending a party in the case of smokers (Niaura et al., 1988). Controlled exposure to reward cues can elicit craving and physiological reactivity (Carter & Tiffany, 1999). Conversely, cues that are negatively associated with reward can dampen craving (Dar, Rosen-Korakin, Shapira, Gottlieb, & Frenk, 2010). The majority of these cues are not innate, so they must have acquired their control over behavior via some form of associative learning.

We know that extinction—the repeated presentation of a predictive cue without the outcome it previously signaled—is an effective way to reduce associatively based behavior. Therefore, it is natural that clinicians have been keen to apply extinction to reduce the impact of reward cues. However, the initial results of such “cue exposure” techniques in clinical practice have been largely disappointing. For example, a review by Conklin and Tiffany (2002) found no consistent evidence for the efficacy of cue-exposure treatment, and we are not aware of any subsequent positive findings. Interestingly, laboratory research confirms that extinction may be surprisingly ineffective in reducing the impact of reward cues on goal-directed behavior.

The most commonly used laboratory procedure for studying the effect of reward cues is known as Pavlovian-instrumental transfer, or PIT. In this procedure, arbitrary cues (conditioned stimuli or CSs) are paired with a reward and the participants are separately trained to perform an instrumental response to obtain the same reward. In the critical transfer test phase, the Pavlovian CSs are presented while the instrumental response is available. The typical result is that a CS trained as a predictor of reward will facilitate instrumental responding for that reward, relative to a nonpredictive control CS (see [Holmes, Marchand, & Coutureau, 2010](#), for a review). Using this approach, animal PIT studies have shown that a CS for food or sucrose continues to produce selective facilitation of an instrumental response for the same reward despite intervening Pavlovian extinction ([Delamater, 1996](#); [Holmes et al., 2010](#)). A similar result has been reported in the only two studies we know of that have tested the effect of Pavlovian extinction on PIT in humans ([Hogarth et al., 2014](#); [Rosas, Paredes-Olay, García-Gutiérrez, Espinosa, & Abad, 2010](#)). Together, these results suggest that the ability of a reward cue to promote reward-directed behavior may survive simple extinction.

However, the existing evidence base is not large, and there is a need for further studies with humans. Such studies would allow an examination of the role of cognitive processes such as expectancy and contingency awareness, which have been shown to play a critical role in human associative learning (e.g., [Mitchell, De Houwer, & Lovibond, 2009](#)) and in reward-based behavior specifically (e.g., [Hogarth, Dickinson, Wright, Kouvaraki, & Duka, 2007](#); [Hogarth & Duka, 2006](#)). Furthermore, most contemporary animal and human PIT studies have used a selective PIT design with two rewards and two response options, in which high motivation effectively renders the test phase a forced choice procedure. Although this design has played an important role in establishing the selectivity of PIT effects, it is not necessarily optimal for testing the absolute ability of a reward-related CS to instigate instrumental action for that reward. To our knowledge there has been no published study of Pavlovian extinction in a “simple” PIT procedure in which participants are free to perform (or not perform) a single instrumental response.

Accordingly, in the present study we employed a procedure we have recently developed ([Lovibond & Colagiuri, 2013](#)) with a single reward and a single instrumental response, and absolute response rate as the primary measure. We see this procedure as providing a laboratory model of the modulation of goal-directed behavior by reward-related cues in

real-world settings. An advantage of this procedure is that it uses a natural high-value reward, chocolate, rather than an abstract or symbolic reward such as points or money. We recorded online reward expectancy in a subset of participants to assess the relationship between Pavlovian expectancy and modulation of instrumental behavior. We used a within-participant design in which one CS was paired with reward, a second CS was paired with reward but subsequently extinguished, and a third CS was never paired with reward. At test, all three CSs were presented to measure their impact on instrumental responding for the reward. To further investigate the role of cognitive processes in PIT, we assessed Pavlovian contingency knowledge by a postexperimental questionnaire and analyzed the data according to the degree of contingency awareness.

Method

PARTICIPANTS

Participants were 90 students (48 female, mean age 20.5 years) from the University of New South Wales (UNSW). Of these, 35 responded to an advertisement and received A\$15 compensation for their time, and 55 participated in partial fulfillment of a course requirement. A further sample of 27 students (19 female, 16 paid, mean age 21.6) was tested with an additional expectancy rating requirement (see Procedure). Of the 117 participants across both samples, 39 described their ethnicity as Caucasian, 28 as Chinese, 19 as South East Asian, 17 as Indian, and 14 as Other. To be eligible for the study, participants had to meet the same criteria as in [Lovibond and Colagiuri \(2013\)](#) regarding chocolate liking and consumption, not being on a diet or allergic to chocolate, and not having eaten chocolate for the preceding 24 hours. However, participants were required not to have eaten any food for 3 hours, rather than the 2 hours used in that study. An additional 17 participants were tested but their data were not included due to failure to earn the required number of rewards during instrumental training (see Procedure). The study was approved by the UNSW Human Research Ethics Committee (approval number HC13026) and all participants provided written informed consent.

Materials

The test room and equipment were the same as described in [Lovibond and Colagiuri \(2013\)](#). In brief, participants were tested individually in a separate room from the experimenter and control equipment, wearing headphones to attenuate external sounds. They sat at a desk with a computer monitor, a box with 6 colored lights, a response button and a Med Associates M&M's® chocolate

Table 1
Experimental Design

	Instrumental Acquisition	Pavlovian Acquisition	Pavlovian Extinction	Transfer Test
button-press	VR10	unavailable	unavailable	extinction
lights	-	A+(6) / B+(6) / C-(6)	A+(3) / B-(6) / C-(3)	A-(2) / B-(2) / C-(2)

Note. VR10 indicates a variable ratio 10 reward schedule; A, B and C refer to red, blue and green colored lights which served as Pavlovian CSs (counterbalanced); + indicates delivery of chocolate; - indicates no chocolate; numbers in parentheses indicate the number of trials of each type, / indicates that trials were intermixed.

dispenser (St. Albans, USA). Three of the lights—red, blue, and green—were used as Pavlovian cues, and the other three lights were never illuminated. A subset of participants in this experiment also gave expectancy ratings by rotating a pointer on a semicircular dial labelled “Certain no chocolate” at the left end and “Certain chocolate” at the right end.

A postexperimental questionnaire was used to assess participants’ knowledge of the Pavlovian contingencies. Participants answered a series of questions regarding the relationships between the three colored lights and chocolate during Pavlovian training. Participants also rated their desire for chocolate and provided demographic information.

PROCEDURE

The design of the experiment is shown in Table 1. The general procedure followed Lovibond and Colagiuri (2013, Experiment 1). Participants were told that at different points in the experiment they would be able to press the button to earn chocolate and that the colored lights would come on. During the Instrumental Acquisition phase, participants could earn M&M’s chocolates by making a criterion number of button press responses on a variable ratio10 (VR10) schedule. They were told they could press the button as often and as quickly as they liked. This phase terminated when 12 chocolates had been earned. In the Pavlovian Acquisition phase participants were told that the button was not available. They were trained with three cues, A, B, and C, consisting of illumination of the red, blue, or green light for 10 s, with color counter-balanced across participants. Two cues (A and B) were followed by chocolate for 6 trials in the Pavlovian Acquisition phase, while the third cue C was also presented 6 times but was never followed by chocolate. In the subsequent Pavlovian Extinction phase, cue B was then presented without chocolate for 6 trials. There were also 3 reminder trials for cues A and C. In the final Transfer Test phase, participants were told that the button was available again. The three cues were each presented twice. No chocolates were delivered during this phase. Trial order in the Pavlovian and Test phases was randomized with a restriction of 2 trials of the same type in a row.

There were two minor changes from the procedure used in Lovibond and Colagiuri. First, we counter-balanced the order of the Instrumental and Pavlovian training phases, in order to explore whether training order had any impact on transfer. Thus, half of the participants received the phases in the order shown in Table 1, whereas the other half received the Instrumental phase after the two Pavlovian phases (Acquisition and Extinction). Second, we gave a minimum of 3 min rather than 2 min of instrumental extinction at the beginning of the Transfer test phase, to help reduce response rate prior to introduction of the Pavlovian cues. In all other respects, the procedure followed Lovibond and Colagiuri.

The primary sample of 90 participants was tested as described above. In addition, 27 further participants were tested with the same procedure but were also asked to provide a continuous rating of their expectancy of chocolate throughout the entire experiment, using the semicircular pointer. They were asked to turn the pointer as often as they needed to in order to convey their current level of expectancy at all times. The continuous expectancy measure was restricted to this separate group of participants because we were concerned that the cognitive load it imposed might interfere with instrumental responding in the Transfer Test phase.

DATA ANALYSIS

Classification of Pavlovian contingency awareness was based on the answers to two forced choice questions about the nonextinguished stimuli: “Which of the three lights was most/least often followed by chocolate?” The correct answers were stimulus A and stimulus C, respectively. Participants who answered both questions correctly were classified as Aware ($n = 70$), those who answered one question correctly as Partially Aware ($n = 14$), and those who answered neither question correctly as Unaware ($n = 6$). To provide an adequate sample size for analysis, the Partially Aware and Unaware participants were combined into a “Nonaware” group ($n = 20$). For the additional sample ($n = 27$) who provided expectancy ratings, 20 were classified as Aware, 4 as Partially Aware, and 3 as Unaware. Due to the small number of Nonaware

participants, analysis was restricted to the 20 Aware participants.

The instrumental response and expectancy data were analyzed by a set of planned contrasts using a multivariate, repeated measures model with alpha set at 0.05 (O'Brien & Kaiser, 1985). The contrast used to test the impact of the CSs in the Transfer Test phase, referred to as "Pre vs CS," compared mean responding during the CS with mean responding in the 30-s period immediately prior to the CS. Contrasts for the Stimulus factor tested all 3 pairwise comparisons between the three CSs A, B, and C. A single group contrast compared the Aware and Unaware participants. Finally, interactions between all combinations of contrasts were tested.

Results

Initial analysis indicated an effect of training order, with the group that received Pavlovian training first making more button-press responses during test than the group that received instrumental training first (40.4 vs. 28.4 responses/min). An exploratory post hoc contrast indicated that this difference was significant, $F(1, 86) = 4.72, p = .033$. However, there were no other significant effects involving training order, so this factor was not included in subsequent analyses. We also carried out exploratory comparisons of the Aware and Nonaware participants. These groups did not differ in mean age (Aware: 20.7 years; Nonaware: 20.0 years, $F[1, 88] < 1$), but there was a significantly higher percentage of females in the Nonaware group (Aware: 47.1%, Nonaware: 75.0%; $\chi^2 = 4.85, p < .05$). We have not previously observed consistent gender differences in awareness, but we report it here for completeness.

Figure 1 shows mean button-press responses in 5-s bins for each CS during the Test phase, separately for Aware and Nonaware participants. For the Aware participants, consistent with Lovibond and Colagiuri (2013), responding appeared to increase during the stimulus that had been consistently paired with chocolate (A), and recovered to baseline over the next 15–20 s. Stimulus C, which had never been paired with chocolate, produced a smaller increase in responding. Responding during the extinguished stimulus B was intermediate between A and C. For the Unaware participants, by contrast, the three stimuli appeared to have little impact on instrumental responding. The impact of the Awareness factor was supported by a significant interaction between Awareness and the Pre vs CS contrast, $F(1, 88) = 9.20, p = .003$, confirming that Aware participants responded more to the CSs than Nonaware participants.

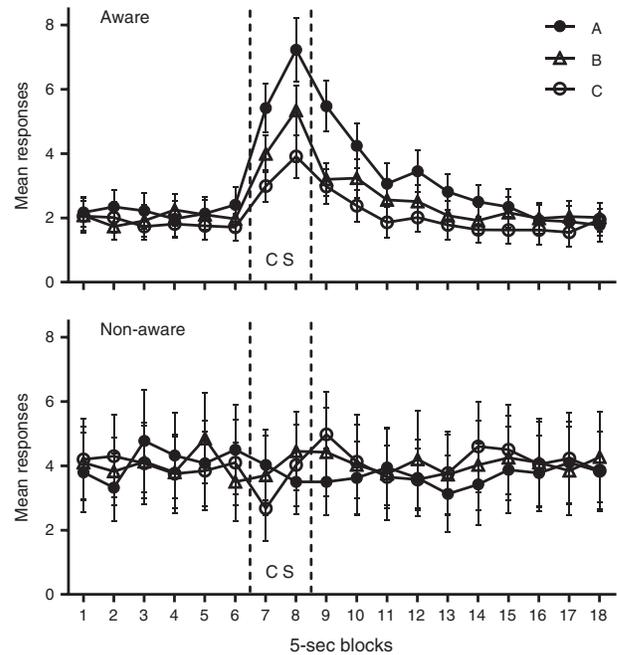


FIGURE 1 Mean instrumental responding in 5-sec bins before, during and after presentation of the conditioned stimuli in the Test phase. A = CS previously paired with chocolate; B = CS paired with chocolate and then extinguished; C = CS never paired with chocolate. Dotted lines indicate onset and offset of the 10-sec CSs. The top panel shows data from participants classified as Aware of the A+/C- contingencies ($n = 70$), and the bottom panel shows data from participants classified as Nonaware (i.e., unaware or partially aware; $n = 20$). Error bars show standard error of the mean.

Further analyses were therefore conducted on the Aware and Nonaware groups separately. In the case of the Nonaware group, no contrasts approached significance (all F s < 1). For the Aware group, there was a main effect for the Pre vs CS contrast, $F(1, 69) = 28.2, p < .001$. This contrast interacted with the A vs C comparison, $F(1, 69) = 17.7, p < .001$, replicating the finding of Lovibond and Colagiuri (2013) that a consistently rewarded CS facilitates instrumental responding relative to a consistently nonrewarded CS. The Pre vs CS contrast also interacted with the A vs B comparison, $F(1, 69) = 5.79, p = .019$, showing that extinction of B reduced its ability to facilitate responding relative to A. However, the interaction between Pre vs CS and B vs C did not reach significance, $F(1, 69) = 3.41, p = .069$. That is, the extinguished CS B did not produce significant facilitation of responding relative to the unpaired control CS C.

As shown in Figure 2, the expectancy data from the Aware participants in the additional sample ($N = 20$) confirmed successful acquisition and extinction of

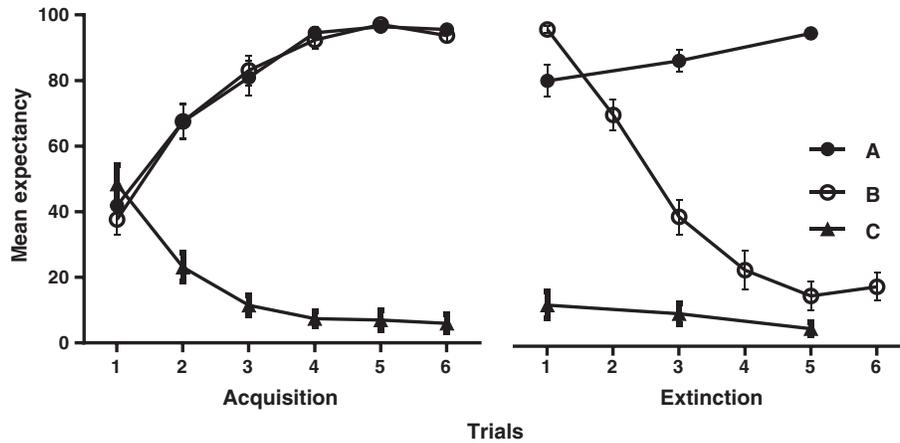


FIGURE 2 Mean chocolate expectancy ratings during the Pavlovian Acquisition and Extinction trials for the additional participants who were asked to make expectancy ratings throughout the experiment and were also classified as contingency aware ($N = 20$). Notation as for Figure 1.

the Pavlovian contingencies. Participants gave higher expectancy ratings to stimuli A and B than to C in the Acquisition phase, $F(1, 19) = 285.6$, $p < .001$, and this comparison also interacted with linear trend over trials, $F(1, 19) = 57.7$, $p < .001$. In the Extinction phase, there was a strong negative linear trend over trials for the nonrewarded stimulus B, $F(1, 19) = 224.3$, $p < .001$.

In the Test phase, the expectancy data followed a similar pattern to the button-press data (see Figure 3). The consistently rewarded stimulus A elicited strong expectancy ratings. The extinguished stimulus B elicited ratings that were lower than to stimulus A, but nonetheless higher than to the consistently nonrewarded stimulus C. This pattern was supported by the statistical analysis. The main effect for the Pre vs CS contrast was significant,

$F(1, 19) = 21.7$, $p < .001$, as were all interactions with CS comparisons: A vs B, $F(1, 19) = 26.5$, $p < .001$; A vs C, $F(1, 19) = 31.3$, $p < .001$; and B vs C, $F(1, 19) = 10.2$, $p = .005$.

Discussion

In this experiment the consistent predictor of chocolate, stimulus A, produced a substantial facilitation of button-press responding relative to the control stimulus C for approximately 20 s. In this respect the data replicate the appetitive PIT effect we have previously reported (Lovibond & Colagiuri, 2013), confirming that reward-associated cues can trigger actions to obtain that reward under free response conditions. Compared with the previous study, the more complex design and the inclusion of an extinction phase appear to have reduced the number of participants who were able to report the training contingency, thus allowing analysis of contingency awareness. This analysis showed that the facilitation effect was only observed in participants classified as contingency aware. This pattern is consistent with previous laboratory research with nicotine conditioning (Hogarth & Duka, 2006) as well as the broader literature on human Pavlovian conditioning (Lovibond & Shanks, 2002). In addition, the ratings of chocolate expectancy provided by the separate group of participants showed a similar pattern to the button-press data across both stimuli and time, supporting the idea that expectancy or another correlated variable may be mediating the PIT facilitation effect. This result is in line with predictions from incentive-based theories of appetitive motivation (e.g., Bolles, 1972; Stewart, de Wit, & Eikelboom, 1984) and is consistent with evidence for the mediating role of expectancy in

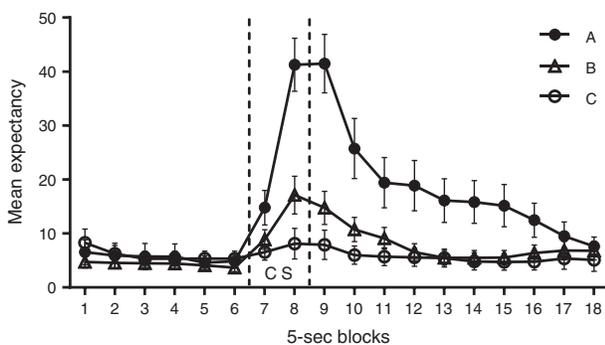


FIGURE 3 Mean chocolate expectancy ratings in 5-sec bins before, during, and after presentation of the conditioned stimuli in the Test phase for the additional participants who were asked to make expectancy ratings throughout the experiment and were also classified as contingency aware ($N = 20$). Notation as for Figure 1.

Pavlovian conditioning more generally (Bolles & Fanselow, 1980; Mitchell et al., 2009).

Most interestingly, the Pavlovian extinction manipulation in this study successfully reduced the ability of a reward-associated stimulus to both facilitate instrumental responding (PIT effect) and elicit reward expectancy. Furthermore, extinction survived the context shift from the Pavlovian to the Test phase arising from availability of the instrumental response. This outcome is inconsistent with the animal research reported by Delamater (1996) where even extended extinction failed to have a substantial impact on the PIT effect. Apart from the obvious species difference, another critical difference between the two studies may have been our focus on absolute response rate rather than response choice in the transfer test. Perhaps even a small amount of remaining associative strength for the Pavlovian stimulus is sufficient to produce a robust advantage for the corresponding response in an otherwise finely balanced choice situation. It would be useful in future research to directly compare the choice and absolute response rate test formats after identical training.

Although extinction was successful in reducing PIT in the present study, it is important to emphasize that its effectiveness was incomplete. It is unknown whether additional extinction training would be capable of eliminating instrumental facilitation altogether. In this regard it is interesting to note that stimulus C, which had never been paired with chocolate, produced a modest degree of instrumental facilitation. We have also observed this pattern in other unpublished studies in our lab. It suggests that even a stimulus with no direct association with reward can elicit instrumental responding under the conditions of a transfer test. This ability of a nonrewarded stimulus to produce facilitation places a lower limit on the likely effectiveness of extinction of a previously rewarded stimulus in this laboratory task. Note, however, that the effect on a nonreinforced stimulus may depend on the baseline level of instrumental responding. We have recently observed suppression of responding by a nonreinforced CS when tested while the instrumental response was still being rewarded (Colagiuri & Lovibond, 2015).

Another point of reference for the present research is a recent series of studies by Van Gucht and colleagues on Pavlovian conditioning with chocolate reward. These researchers have shown that arbitrary stimuli paired with chocolate elicit higher ratings of chocolate desire or “craving” than control unpaired stimuli. In several studies, extinction of the stimulus previously paired with chocolate reduced ratings of chocolate expectancy but did not reduce ratings of chocolate craving (Van Gucht, Vansteenwegen,

Beckers & Van den Bergh, 2008; Van Gucht, Baeyens, Vansteenwegen, Hermans, & Beckers, 2010; Van Gucht, Baeyens, Hermans, & Beckers, 2013). Their result would predict that extinction might similarly fail to impact on PIT, if PIT is driven by desire for the reward. In the present experiment, we observed little evidence for dissociation between the expectancy measure and the PIT measure, although the extinguished cue B was numerically closer to the control cue C on the expectancy measure. More importantly, we did observe a significant reduction in the magnitude of the PIT effect as a result of Pavlovian extinction. It may be that the craving measure employed by Van Gucht and colleagues behaves similarly to other measures of liking or evaluation, which have previously been shown to be insensitive to extinction in the evaluative conditioning literature (Baeyens, Crombez, Van den Bergh, & Eelen, 1988). However, more consistent with the current study, Van Gucht and colleagues have also shown that chocolate exposure can reduce craving in participants who were selected for their high pre-existing craving rather than being given direct conditioning in the laboratory (Van Gucht, Vansteenwegen, Beckers, Hermans, et al., 2008). It is clear that further research will be required to understand the conditions that best promote reduction in reward expectancy, craving and instrumental behavior.

In conclusion, there were three main outcomes from this study. First, we replicated the finding that Pavlovian cues for reward can facilitate reward-directed instrumental action (PIT) in humans. Second, we found that the PIT effect was paralleled in the expectancy measure and also that it was restricted to participants who were classified as aware of the Pavlovian contingencies, supporting the role of cognitive processes in reward-directed behavior. Finally, we found that extinction produced a significant reduction in the magnitude of the PIT effect. This finding encourages the idea that exposure to reward-related cues may have a role to play in the management of excessive appetitive behaviors such as gambling, binge-eating and drug abuse. However, extinction did not eliminate the potency of reward cues entirely and other laboratory evidence suggests that extinguished cues have a residual associative strength that can exert substantial influence on behavior, especially after a context change or the passage of time (e.g., Bouton, 1988). Clinical evidence also suggests that cue exposure is not by itself a sufficient treatment strategy (Conklin & Tiffany, 2002). However, it may form an important part of a management program that includes active training in how to resist the impact of reward cues. The current

finding that the PIT effect is closely associated with contingency awareness and reward expectancy further suggests that cue exposure might be usefully combined with elements of cognitive training such as relapse prevention (Marlatt & Gordon, 1985).

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