On the Value of Nonremovable Reminders for Behavior Modification: An Application to Nail-Biting (Onychophagia)

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On the Value of Nonremovable Reminders for Behavior Modification: An Application to Nail-Biting (Onychophagia)

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Abstract

The authors examined the effectiveness of a novel behavior modification method for dysfunctional and impulsive habits, based on nonremovable reminders (NrRs). NrRs were implemented by having participants wear nonremovable wristbands designated to constantly remind them of their resolution to quit the targeted habit (nail-biting). Participants were 80 nail-biters who resolved to quit. The NrR approach was contrasted with an aversion-based behavioral modification technique. Recovery was assessed after 3 and 6 weeks of treatment and in a 5-month follow-up. The NrR method was associated with lower drop-out rate and was as successful as the aversion-based method altogether. When considering only non-dropouts, the aversion-based method was more effective. This suggests that the use of constantly present reminders broadens the target population that can benefit from reminders in the course of behavior modification.

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In an experimental field study, we evaluated the use of reminders for modifying an impulsive and maladaptive habit. Our focus was on the type of reminders that we refer to as "nonremovable," which are reminders that do not require renewal or reapplication, and whose removal, once set, is quite costly so that most people do not remove them (for instance, it could be difficult and effortful to remove them). Past studies have shown that reminders can be effective for increasing people's adherence to their goals. For example, reminders have been successfully used for helping doctors make required follow-ups (Vashitz et al., 2009) and checkups (Bitan, Meyer, Shinar, & Zmora, 2004), and in cognitive behavioral therapy as a means for prompting patients of their required routines (Spence et al., 2008). We examine the utility of reminders for promoting a goal when there are conflicting motives, as in the case of resolving to quit a maladaptive habit. Specifically, we focus on the ability to use reminders to avoid impulsive behavior, namely, behavior that is not regulated and does not consider long-term goals but rather results from immediate satisfaction motives (Baumeister, 2002).

The notion that reminders should be helpful in the modification of habitual impulsive behavior is driven by two major theories. First, Bandura's (1989) sociocognitive theory suggests that means of affecting behavior should be regulated by the person's own agency. The concept of *human agency* implies that self-set reminders can aid self-regulation or the realization of one's resolutions. Yet, although Bandura's applications of this approach focused on goal setting and on improving individuals' beliefs of self-efficacy in general, they did not extend to address issues related to difficulties in remembering the goals when conflicting motives arise.

The role of memory in regulating behavior was emphasized by the cognitive-motivational theory (CMT; Finn, 2002). Originally suggested to explain vulnerability to alcoholism, CMT holds that the ability to inhibit previously dominant behavior is moderated by working-memory processes, which modulate the activation of relevant information and the resistance to distraction. CMT is consistent with past theories of addiction arguing that addicts have a particular difficulty in maintaining goals on the introduction of temptation (Bartzokis et al., 2000; Bechara et al., 2001; Grant, Contoreggi, & London, 2000), but it further suggests that this may be due not only to poor impulse control and related motivational biases but also due to weak memory processes.

Accordingly, self-set reminders acting as memory aids are hypothesized to be useful for offsetting this working-memory deficit.

The problem with reminders in this context is that normally they can be removed, and therefore users may well forget to attach or reactivate them (a phenomenon often described in research involving reminders; see, for instance, Leonard & Rayport, 1997; Short, O'Regan, Lew, & Oh, 1993). If faulty working-memory processes are assumed to contribute to the onset or persistence of impulsive habits, then it will be unreasonable to expect that those succumbing to these habits will remember to reactivate the reminder as needed. Accordingly, we chose to implement nonremovable type of reminders. This ensures that the continued availability of the reminder does not depend on the person's memory skills. In other words, this type of reminder solves the problem of "who will guard the guards." The guards (i.e., the reminders) are self-guardable by their design. We made deactivation of the reminder quite costly: Removing the reminder destructed it so it could not be restored, which implied the termination of the training process (and loss of the incentives we offered to successful quitters).

We conducted an experimental study in the context of nail-biting (onychophagia) to examine the value of nonremovable reminders (NrRs) compared with an existing benchmark solution entailing aversive but removable reminders. Nail-biting involves chronic biting of the fingernails and cuticles. In its severe forms, it causes not only aesthetic concerns—and consequently, social embarrassment—but also bleeding, infections, and dental problems (Fuqua & Brosh, 2006). The behavior is highly common, with estimates of prevalence among adults ranging from 20% (Ballinger, 1970) to more than 50% (Hansen, Tishelmian, Hawkins, & Doepke, 1990). Nail-biting is considered to be in part impulsive and in part compulsive (Stein, Zohar, & Simeon, 2002). Although we do not know of studies that examined working-memory impairment associated with nail-biting, studies on individuals with similar self-damaging behaviors (e.g., trichotillomania) do show that they exhibit such impairments (e.g., Chamberlain et al., 2007; Keuthen et al., 1996).

Two behavior modification methods for nail-biting have been identified as markedly effective in the literature: habit reversal (see Azrin & Nunn, 1973; Woods & Twohig, 2001) and aversion techniques involving the application of bitter substance to the fingernail area (Allen, 1996; Silber & Haynes, 1992). As Fuqua and Brosh (2006) point out, whether any of these methods outperforms the other is unclear. We set to examine the effectiveness of a NrR approach for changing this dysfunctional habit.

Participants—nail-biters who expressed willingness to quit—were randomly assigned into either one of two conditions. In the NrR condition,

participants wore nonremovable vinyl wristbands for the entire treatment period (6 weeks). The wristbands were designated to represent participants' resolution to refrain from biting their nails and remind them of it. In the aversion condition, participants were treated with the commonly applied aversion technique. They were provided with bitter-tasting nail enamel and were required to apply it routinely. A secondary manipulation pertained to salience of the reminder. Half of the participants in the NrR condition wore the wristbands on their wrists (providing high visual salience) and half on the ankles (low salience). Half of the participants in the aversion condition were provided with colored, bitter nail enamel (high salience), and the other half used transparent enamel (low salience). This enabled us to validate whether any advantage of the NrR method is due to the transparency and lack of salience of the normally used bitter nail enamel.

The aversion technique essentially involves reinforcement learning, but it also constitutes a reminder, which is self-terminating and requires reactivation. Specifically, although the presence of the aversive substance likely comes to serve as a discriminative stimulus, indicating that placing the nail in one's mouth will result in foul taste, it also serves as a reminder of one's goal of avoiding nail-biting. Each time the person notices the nail enamel, he or she is presumably reminded of the reason for putting it there. The aversion method and the NrR method thus seem to have complementary advantages. The former includes punishment that substantially increases the cost of biting the nails, whereas the latter does not require reactivation and therefore is relatively immune to participants' lack of cooperation in maintaining the reminder (e.g., due to forgetting).

Our first prediction concerning the difference between the NrR and the aversion-based methods concerned drop-out participants. Quite often individuals who drop out are those who are not able to comply with the behaviors requested during treatment (Haynes, McDonald, & Garg, 2002). Compliance was considered to be easier in the NrR condition because reactivation of the reminders was not necessary. Therefore, fewer participants were predicted to drop out in the NrR condition than in the aversion condition.

Our second, related, prediction pertained to the outcomes of the program. The aversion technique has been documented to be quite successful (Allen, 1996; Fuqua & Brosh, 2006; Silber & Haynes, 1992). However, high treatment effectiveness can only be predicted for those participants who (remember to) reactivate it by applying the bitter substance to their nails on a regular basis. For other participants, the effect could be expected to be weaker. However, NrRs do not depend on consistent reactivation. Therefore, we hypothesized that the relative advantage of the aversion condition would be higher when

considering only those who comply with the program (i.e., only non-dropouts), but it should diminish when considering all participants (i.e., dropouts as well).

Individual Differences and Prediction of Successful Recovery

Above and beyond the effect of the behavioral modification method, we expected to observe individual differences in the degree of success in recovery from nail-biting. We tested the predictive power of several measures of self-control and decision making in capturing these individual differences, by correlating them with the participants' improvement scores.

Adhering to the program regulations involves putting off the reinforcements associated with nail-biting in favor of their long-term goals to avoid nail-biting. Therefore, we examined whether the participants' delay of gratification predicts their successful recovery from nail-biting. As commonly done in the literature, we assessed delay of gratification using a Delay Discounting Task (Kirby, 1997), a task that measures the devaluation of future rewards in comparison with immediate ones. Delay discounting has been associated with numerous dysfunctional behaviors, such as drug (Bickel & Marsch, 2001) and alcohol (Petry, 2001) dependence, and cigarette smoking (Bickel, Odum, & Madden, 1999). We further tested whether individual differences in self-control could predict treatment outcomes, using the Self-Control Questionnaire (Tangney, Baumeister, & Boone, 2004). Self-control was found to be negatively associated with measures of eating disorders, alcoholism, and psychological pathologies (Tangney et al., 2004).

In addition, we examined another aspect of the cognitive style implicated in nail-biting, involving the pursuit of immediate gains despite potential losses. Many nail-biters report that biting their nails has immediate positive consequences for them, such as relief of stress (Hansen et al., 1990). Thus, by biting their nails, they seem to favor these pleasant consequences and to discount other negative consequences that are immediate and clearly observed and felt (pain, injury, esthetic concerns, and so on). A simple variant of the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994), called the Foregone Payoff Gambling Task (FPGT; Agay, Yechiam, Carmel, & Levkovitz, 2010), was used to examine the trade-off between the effect of rewards and penalties. It involves repeated choices between risky alternatives—yielding gains as well as losses—and safe but invariable alternatives. The task was previously found to be sensitive to attention deficit hyperactivity disorder (ADHD; Agay et al., 2010), a disorder known to be associated with a variety of impulsive behaviors such as nail-biting (Ghanizadeh, Mohammadi, & Moini, 2008).

Table 1. Initial Group Sizes and Drop-Out Numbers and Percentages in the NrR Condition and in the Aversion Condition, for the Two Subconditions

	NrR		Aversion	
	Salience	Nonsalience	Salience	Nonsalience
No. of participant	21	20	20	20
No. of dropouts (%)	2 (10)	3 (15)	5 (25)	5 (26)

Note: NrR = nonremovable reminder.

Method

Participants

Participants were 80 students (51 males and 29 females) who replied to ads spread around campus. The ads encouraged nail-biters who wished to quit to participate free of charge in an experimental nail-biting cessation program. Participation was voluntary, and participants provided an informed consent. Participants' age ranged between 19 and 41 years with a mean of 25. They were randomly allocated into the four experimental groups (group sizes are presented in Table 1). At the end of the first session, an award of NIS 300 (about US$75) was announced for the 4 participants whose nails would improve the most following treatment. The study was conducted in compliance with the institutional review board.

Design and Materials

The program lasted 6 weeks. In the NrR condition, participants wore nonremovable vinyl wristbands, of the type used for identification at theme parks, visitor centers, and other public venues. Band width was 1.5 cm. Participants could choose between 5 colors of wristbands: black, white, red, pink, and gold. Once worn and buckled, the bands could not be removed without tearing them. In the salience subcondition, bands were worn on both wrists; in the nonsalience subcondition, bands were worn on both ankles.

In the aversion condition, participants were provided with bitter-tasting nail enamel by Dexxon Ltd. In the salience subcondition, the bitter enamel was colored; in the nonsalience subcondition, it was colorless. The enamel is colorless in its original form, and colorful bitter enamel was created by mixing the enamel with cosmetic nail enamel of various colors.[1] Participants in

the salience condition could choose their preferred color from a variety of 20 colors. The enamel was provided in 8 ml plain glass containers, without any manufacturer labels.

Measures Used for Predicting Recovery

Delay Discounting Task. This task (Kirby, 1997) takes the form of auctions in which participants are requested to indicate the amount they are willing to pay today, to obtain a larger sum at a given point in the future (for instance, US$25 following a 10-day delay period). High bids increase one's odds of winning the auction, but naturally, they also decrease gain size. Therefore, higher bids indicate higher willingness to delay gratification, particularly as the delay periods grow longer. Second-price auctions are used as means of bidding one's true present value, which in these auctions is the response with the highest expected value. A participant's relative willingness to delay gratification in this task is measured by a parameter, denoted k, calculated based on the bids made for different proposed amounts and delay periods. High willingness to delay gratification is indicated by low values of k. Some of the auctions were selected randomly and played out for real money at the end of the experiment (see. Carter, Meyer, & Huettel, 2010). Winning participants paid their indicated bids (in NIS) and received their earnings in due time. Participants were informed of this prior to proposing their amounts.

Self-Control Questionnaire. This questionnaire (Tangney et al., 2004) consists of 36 items (e.g., "I wish I had more self-discipline" and "I have a hard time breaking bad habits"). Participants self-rate themselves on each item on a scale of 1 (*not at all*) to 5 (*very much*). The internal consistency of the questionnaire was satisfactory (Cronbach's $\alpha = .86$ in the current sample).

FPGT. In this task (Agay et al., 2010), participants make repetitive selections from four decks of cards without initial information as to the payoffs they yield and with the goal of maximizing their profit (see. Figure 1). Two of the decks produce a constant, safe outcome and the other two produce a risky outcome (i.e., there is a variety of potential outcomes and losses may occur as well as gains). In the current study, the two safe decks produced an outcome of 20 points gained on every selection, and the two risky decks yielded +50, −50, +100, −100, +150, −150, +200, or −200 points with equal probability. Note that the expected value of the risky decks is zero, therefore their choice is inadvisable in the long run. On selecting a deck, participants are shown the outcome sampled from its respective payoff distribution as well as the outcomes for nonselected alternatives (known as foregone payoffs). This latter

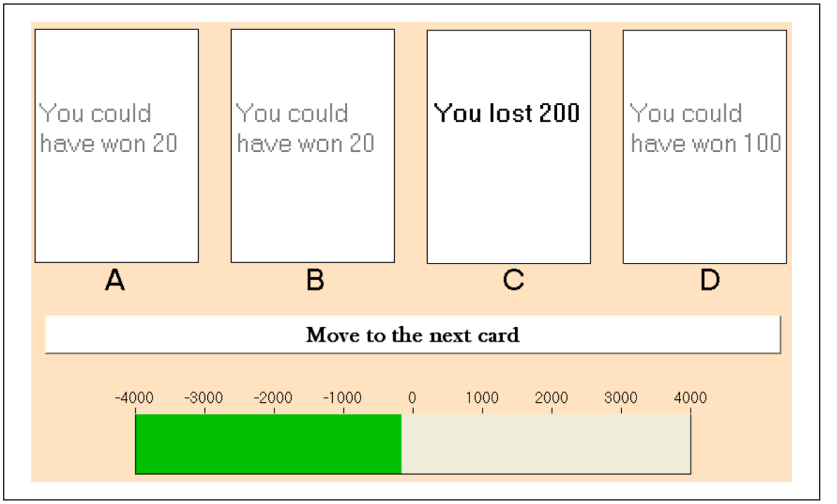

Figure 1. Screen shot of the Foregone Payoff Gambling Task (FPGT)

feature increases salience of the potential gains as the participant is presented with forgone high gains from at least one of the risky alternatives in 75% of the trials.

Procedure

Each participant attended three individual sessions at the laboratory in the course of 6 weeks. The first session included an overview of the program, describing its goals and implementation. Participants were asked to answer a questionnaire concerning their past and present nail-biting habit, and to complete the various prediction measures. They also had their nails observed and assessed using the Malone–Massler scale (Malone & Massler, 1952). Following the assessment procedure, participants were provided with the wristbands or bitter nail enamel and were given instructions regarding their use. These were:

> Every time you feel the urge to bite your nails, you are requested to perform the following actions instead: 1. Hold still; 2. Think of your decision to quit biting your nails; 3. Try to feel the place where the bands touch your skin/Try to feel the substance on your nails; and 4. Avoid biting the nails.

Wristbands were presented as symbols of the participant's resolution to refrain from nail-biting, and the participants in the NrR condition were instructed to

Table 2. Means (*SD*s) for the Self-Report Items Concerning Nail-Biting in the NrR Condition and in the Aversion Condition, and *p* Values of *t* Tests Comparing These Two Conditions

	Session 1	Session 2	Session 3	Follow-up
"How many times a day do you bite your nails?"				
NrR	10.34 (9.30)	1.78 (2.93)	2.21 (5.59)	2.96 (2.57)
Aversion	15.24 (19.86)	2.09 (5.72)	1.26 (4.13)	4.25 (9.08)
p	.17	.79	.46	.54
"For how long (in minutes) do you bite your nails each time?"				
NrR	6.32 (9.06)	1.54 (5.51)	1.47 (5.48)	2.77 (3.93)
Aversion	5.26 (8.07)	0.86 (2.03)	0.68 (1.47)	1.33 (1.58)
p	.58	.54	.47	.13

Note: NrR = nonremovable reminder.

keep the bands on until the end of the program. They were informed that this was required for successfully completing the training and obtaining the award. Participants in the aversion condition were instructed to use the enamel twice a day or more if needed, so that they would have some substance on their nails at any time (manufacturer instructions for the bitter enamel are that it should be renewed at least every 12 hr for efficient use).

Assessment of Nail-Biting

Nail-biting was assessed using the index by Malone and Massler (1952). Each nail was observed and given a score between 0 (*intact*) and 3 (*severely bitten*). The scores from all 10 fingers were summed to a total score. The observation was done by two experimenters, and interrater reliability was established (Cronbach's α of .95). Assessment took place in the first session and in two sessions held 3 and 6 weeks later. In addition, participants completed self-report questionnaires about the frequency and intensity of their nail-biting (see Table 2 for the exact items used).

Results

Initial Assessment

The vast majority of participants presented quite severely bitten fingernails in the first session (see Figure 2). The mean score of the Malone–Massler score in the first session was 23.94 out of 30 (*SD* = 5.68, median = 25.50, mode = 29). No initial differences were found in the Malone–Massler score

between the two experimental conditions ($F < 1$). Participants' self-report of their present nail-biting habits can be seen in Table 2. Regarding past behavior, median reported age of nail-biting onset was 7 years, and all participants reported to have tried to quit biting their nails at least once in the past (median = 3 times).

Dropout During the Program

Of the 80 participants who completed the first session, 15 participants (18%) did not attend either the third session or both the second and third sessions. The number of dropouts per group can be seen in Table 1. Rate of dropout in the aversion condition (26%) was somewhat higher than in NrR condition (12%), although the difference in drop-out rates between these two conditions only approached significance, $Z = 1.54$, $p = .06$. The practical significance of the difference was high, with an odds ratio of 2.17. Drop-out rates did not significantly differ in the two salience subconditions (see Table 1).[2]

In the NrR condition, all participants who completed the program presented their intact wristbands in the last session (after 6 weeks). Of those participants in the aversion condition who completed the entire program, 64% indicated that at the beginning of the program they applied the enamel as instructed. Mean length of period in which the enamel was used as instructed was reported to be nearly 2 weeks (13.72 days, $SD = 8.5$). All participants reported a decrease in enamel-use frequency as the program proceeded, and five participants (17%) reported that they had not applied the enamel at all in the second half of the program. The most common reasons provided for this decrease were forgetfulness and successful cessation of nail-biting.

Nail-Biting After 3 and 6 Weeks of Program: Without Drop-Out Participants

We first analyzed the results without including participants who dropped out before completion of the program. As demonstrated in Figure 2, similar trends appeared in all four groups: a steep decrease in nail-biting scores in the first half of the program and maintenance of achievements through the second half. Nevertheless, the positive trend was larger in the aversion condition. To determine the significance of this difference, results were submitted to a two-way repeated measures ANOVA, with treatment progress (at the three time points: initial, middle, and final sessions) as the within-subject factor and condition (NrR vs. aversion) and subcondition as between-subject variables. The

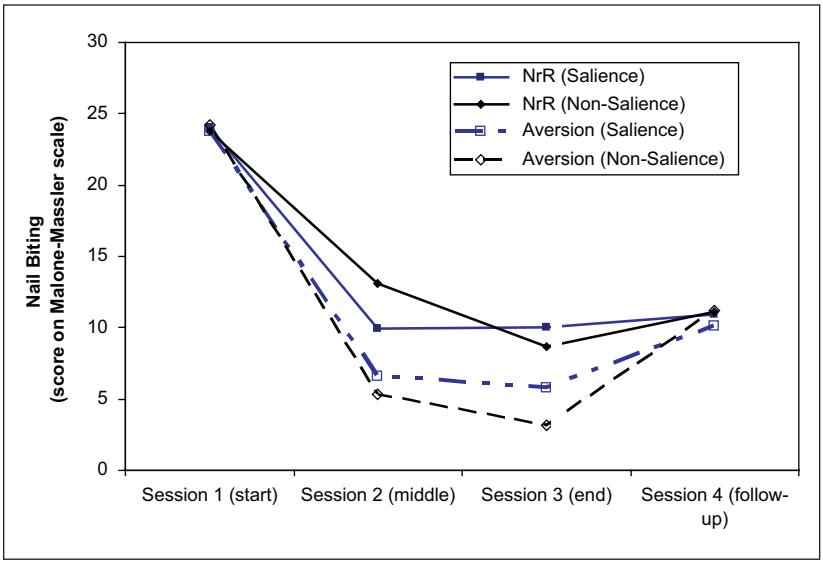

Figure 2. Mean nail-biting score in the three sessions of the program and follow-up examination for non-dropouts only: A comparison of the NrR condition and the aversion condition under the salience and nonsalience subconditions
Note: NrR = nonremovable reminder.

assumption of sphericity was violated in Mauchly's sphericity test, $\chi^2 = 15.38$, $p = .0005$, and so within-subject analyses took the multivariate approach.

There was a significant within-subject effect, Wilks's lambda: $F(2, 59) = 110.94$, $p < .0001$, indicating that both NrR and aversion methods were significantly effective in reducing nail-biting levels throughout the program. However, this effect was interacted by the experimental condition, Wilks's lambda: $F(2, 59) = 3.35$, $p = .042$, revealing an advantage to aversion-based method. No interaction was found with salience level, Wilks's Lambda: $F(2, 59) = 1.16$, $p = .32$, and a three-way interaction was not detected either, Wilks's Lambda: $F(2, 59) < 1$. Thus, when considering only non-dropouts it appears as if the aversion-based method has an advantage.

Nail-Biting After 3 and 6 Weeks of Program: All Participants

We next conducted the same analysis for all participants, including dropouts. For the participants who dropped out before the third session, we used the last Massler–Malone score (from either the first or second session) wherever

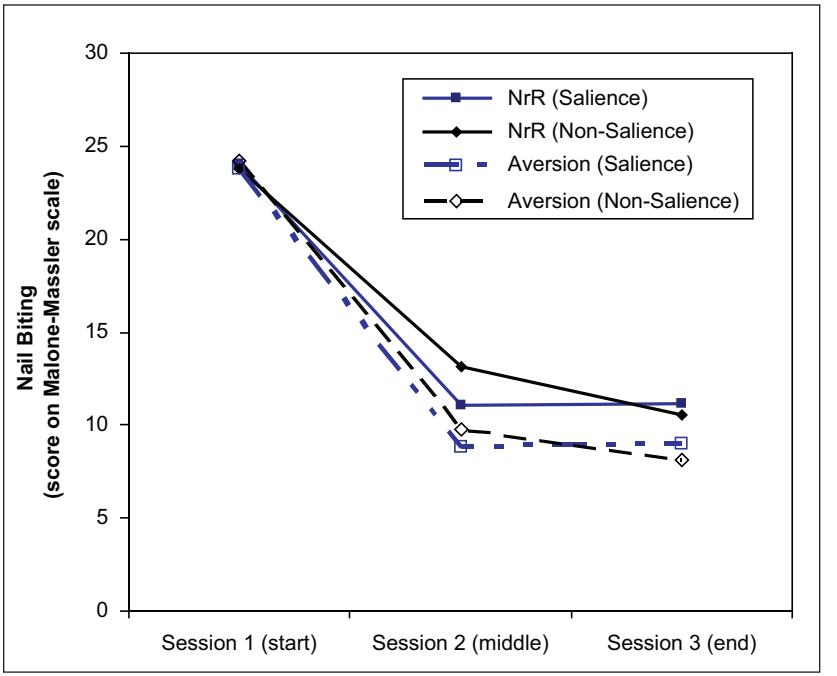

Figure 3. Mean nail-biting score in the three sessions of the program for all participants (dropouts and non-dropouts): A comparison of the NrR condition and the aversion condition under the salience and nonsalience subconditions
Note = nonremovable reminder.

a more recent score was missing. This simple imputation was done based on the assumption that drop-out participants were not likely to improve spontaneously: because virtually all participants reported on the first session that their nail-biting was ongoing for years and resistant to past attempts to recover, this seemed a reasonable assumption (see. Higgins, White, & Wood, 2008).

Our results are summarized in Figure 3. As can be seen, the difference between the NrR and aversion condition was eliminated when considering all participants, and similar trends appeared in all four groups. The results were submitted to a two-way repeated measures ANOVA as before. The assumption of sphericity was violated in Mauchly's sphericity test, $\chi^2 = 30.39$, $p < .0001$, and the analysis therefore took the multivariate approach.

Results reveal a significant within-subject effect, Wilks's Lambda: $F(2, 75) = 70.80$, $p < .0001$, indicating that both the NrR and aversion methods were successful in reducing nail-biting levels as the treatment progressed. However, this time, the effect was not interacted by the experimental condition, Wilks's lambda: $F(2, 75) < 1$, that is, both methods were equally effective. No additional main or interaction effects were found. Thus, when adding up the participants who dropped out during the program, the NrR method becomes more competitive.

Follow-Up Analysis: Nail-Biting 5 Months Past Program Completion

To examine sustainability of treatment results over time, we contacted program participants about 5 months after its completion. Only participants who had completed the program in full were contacted at this stage. A total of 42 participants (53%) attended the follow-up session. As can be seen in Figure 2 and Table 2, differences between conditions at this stage were small. We conducted an analysis of variance to test for potential effects of behavioral modification method or salience on follow-up findings, and no such effects were found, $F(3, 38) = 0.02$, $p = .99$. In addition, the follow-up data indicate that the program's achievements were maintained over time. A paired t test confirmed that nail-biting scores in the follow-up session were lower than those measured at the beginning of the program, $t(42) = 8.05$, $p < .0001$, although being somewhat higher from those measured at the end of the program, $t(42) = 4.13$, $p = .0002$. Hence, use of NrRs was equally successful as the aversion method in fostering a lasting change of behavior.

Individual Differences and Prediction of Recovery

The improvement in the condition of the nails was calculated by subtracting the Malone–Massler score of Session 2, Session 3, or the follow-up session from the score of the initial session. We correlated the improvement scores against the various predictors described earlier. None of these predictors was found to correlate with the initial Malone–Massler scores as measured on Session 1. This implies that the initial severity of nail-biting did not affect the associations found. Table 3 presents the correlations of the tested predictors with progress in the NrR and aversion conditions. Interestingly, different variables predicted the rate of improvement under the two methods.

Improvement in the NrR condition (see Panel A of Table 3) was predicted by the FPGT. This measure was more successful in predicting long-term

Table 3. Pearson Correlations Between Various Predicting Variables and Improvement in Nail-Biting: Number of Past Attempts to Quit, Delay Discounting (Mean *k* Parameter), Score on the Self-Control Questionnaire, and Performance on the FPGT (Mean Proportion of Risky Choices)

Panel A: NrR Condition

	Session 2 (3 weeks)	Session 3 (6 weeks)	Follow-up (5 months)
No. of past attempts	.031	−.003	−.362
Delay discounting	.036	.078	.071
Self-control	.194	.208	.270
FPGT	−.277	−.161	−.429*

Note: FPGT = Foregone Payoff Gambling Task; NrR = nonremovable reminder.
*$p < .05$.

Panel B: Aversion Condition

	Session 2 (3 weeks)	Session 3 (6 weeks)	Follow-up (5 months)
No. of past attempts	.002	.007	.038
Delay discounting	−.244	−.274	−.052
Self-control	−.166	−.045	−.017
FPGT	.112	.092	.120

Note: FPGT = Foregone Payoff Gambling Task.

maintenance than middle or end results of the program. It appears that, in accordance with our hypothesis, a general tendency for seeking large gains in spite of frequent losses may hinder attempted behavioral change, but only when the mechanism of change involves the use of reminders that retain the original incentive structure implicated in the habit.

Number of previous attempts to quit nail-biting was also negatively correlated with long-term maintenance of program's results, indicating that individual differences in past ability (or inability) to change a maladaptive habit can predict the next trial's success. Although the correlation was not significant, it is worth noticing because many of the quitting attempts reportedly took place in the participants' childhood and adolescence and because this correlation remains about the same when the initial severity of nail-biting (Session 1's Massler–Malone score) is controlled for. Finally, the *k*-parameter of the

Delay Discounting Task and the Self-Control Questionnaire were not significant predictors in any of the conditions.

Discussion

Our findings demonstrate that reminders that are "nonremovable," in the sense of not necessitating renewal and being relatively immune to removal, can be effective. Moreover, we have demonstrated that, compared with a traditional aversion treatment (using reminders that required renewal), NrRs had a particular effect in preventing treatment noncooperation. Drop-out rate was lower when the reminders took the form of nonremovable wristbands. Also, overall success of the NrR approach compared with the aversion method was greater when adding up the individuals who withdrew from the program at various stages following the initial meeting. Our interpretation of these findings is that NrRs have an effect at the edges, for those individuals who find it difficult to renew the reminders/reinforcers in the aversion condition.

More broadly, the results imply that NrRs may counteract the cognitive problems commonly associated with impulsive habits, which interfere with the success of regular behavioral modification methods. When a method requires the participant to remember to enable or activate some of its elements, its success is interacted with the participants' memory skills. The NrR approach overcomes this problem by having the reminders constantly present and not requiring reactivation. This was implemented in our study by the nonremovable wristbands, which could only be taken off at the cost of terminating program participation. Alternative means are available for generating NrRs in nonexperimental settings. An example would be externally programmed short message service (SMS) or email messages (Downer, Meara, & Da Costa, 2005).

Our choice of the reminder approach was driven by the CMT of addiction (Finn, 2002), which indicates that sensitivity to various forms of impulsive behavior is exacerbated when working-memory resources are depleted. For example, depleted working-memory capacity was found to be associated with impulsive decision making on Delay Discounting Tasks (Hinson, Jameson, & Whitney, 2003; see related results in Bechara & Martin, 2004; Finn, Mazas, Justus, & Steinmetz, 2002). Our findings go beyond the CMT by suggesting that although individual differences in working-memory resources affect individuals' ability to control their behavior, external interventions can help overcome memory difficulties and enhance self-regulation.

A behavioral modification method for nail-biting based solely on reminders has practical advantages over other leading treatment methods. First, as mentioned earlier, it does not rely on one's memory as much as other methods do, which is an advantage especially for participants prone to forgetfulness (in most

other methods, the participant needs to remember to use the method). Second, use of NrRs is self-applicable and low maintenance, compared with the other leading methods. For example, habit reversal (Azrin & Nunn, 1973; Woods & Twohig, 2001) often requires recruitment of a support person, who may not always be available. Aversion treatment requires consistent application of the bitter substance to remain effective. In addition to being time-consuming, this method has other costs: The bitter flavor often expands to items held in one's hands, making it hard to eat or to prepare food (thus hindering the suitability of this treatment for people who take care of children, for instance).

Naturally, as the current sample was rather homogeneous, applicability of the NrR approach to other populations has yet to be checked. Additional limitations of the present study involve the particular incentive regime used (i.e., the financial award to those who improved the most), which may have affected the relative advantage of the different methods.

There is a growing body of evidence from decision research that choice is a prominent factor in dysfunctional habits (Bechara, 2005). Patterns of impaired decision making or impulsive choice have been found in association with drug abuse (Bechara, 2005; Bechara & Martin, 2004; Finn, 2002; Finn et al., 2002; Yechiam, Busemeyer, Stout, & Bechara, 2005), overeating (Dawe & Loxton, 2004), and cigarette smoking (Bickel, Odum, & Madden, 1999). However, despite the scope and depth of description and analysis of such phenomena, little has been done in attempt to apply the findings so as to promote positive change. The subfield of decision architecture, or decision change, seems to focus mostly on economic decisions (Thaler & Sunstein, 2008). The current work, featuring an application of a theory of individual difference in choice behavior (Finn, 2002) to behavioral modification of an impulsive and dysfunctional habit, is innovative in this respect. There is a growing call for the design and implementation of further methods to tackle dysfunctional behavior and to help individuals live up to their resolutions by using decision architecture.

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Notes

1. A pilot test of the bitter substance with cosmetic nail enamel showed that it was rated as equally bitter and unpleasant as the original substance 1 hr and 6 hr following treatment.
2. Also, dropout was not affected by the initial severity of the nail-biting condition. The initial Massler–Malone score of drop-out participants was not different than that of the other participants, $t(78) = 0.58$, $p = .56$.

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