Primed for Health: Future Thinking Priming Decreases Delay Discounting

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Objective: Delay discounting, the propensity to devalue delayed rewards, has robust predictive validity for multiple health behaviors and is a new therapeutic target for health behavior change. Priming can influence behaviors in a predictable manner. We aimed to use the Future Thinking Priming task, administered remotely, to reliably decrease delay discounting rates. **Methods:** In this pre-post randomized control group design, participants completed multiple delay discounting measures at baseline; then, 2 weeks later, they were randomized to Future Thinking Priming or Neutral Priming conditions. We hypothesized that Future Thinking Priming would significantly decrease delay discounting rates accounting for baseline delay discounting rates and time in repeated measures analyses. **Results:** Participants randomized to Future Thinking Priming (N = 783) demonstrated significantly lower delay discounting rates post-intervention than those randomized to Neutral Priming (N = 747) on multiple delay discounting measures and magnitudes. **Conclusions:** A single administration of Future Thinking Priming produces statistically reliable reductions in delay discounting rates. The task is brief, can be administered remotely, and is highly scalable. If found to support behavior change, the task might be disseminated broadly to enhance evidence-based behavior change interventions. Future research must determine optimal exposure patterns to support durable health behavior change.

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Unhealthy behaviors such as tobacco use, eating unhealthful foods, physical inactivity, excess alcohol use, and illicit drug use continue to contribute significantly to the primary causes of preventable death, disease, and disability.[1-4] Differences in these health behaviors also contribute to a widening gap in socioeconomic and racial health disparities.[1,5-7] Historically, health behavior models have relied on conscious internal factors such as intention, readiness, and motivation to change, self-efficacy, active learning, cuing, and cognitive components such as outcome expectancies.[8-12] Many effective behavioral interventions have been developed using these models and whereas the intervention effect sizes on the behavioral intention or readiness to change are medium to large, the effect sizes on the actual performance of health behaviors is sometimes quite small.[13] Interventions focused on behavior change intention are often less successful when several common challenging elements are present such as less perceived behavioral control, significant environmental support for maladaptive automatic behaviors, and when unhealthy behaviors are performed in social contexts.[13] Most authorities agree that there is considerable room for improvement; moreover, innovative approaches are

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needed to have a greater impact on the prevalence of unhealthy or problematic behaviors.

Evidence-based behavioral treatments to improve unhealthy behaviors are grounded in cognitive-behavioral approaches and focus on becoming aware of maladaptive, automatic patterns of thought and behavior, and applying new strategies to inhibit unwanted behaviors and activate desired behaviors.[14-16] Although these approaches are effective, they require considerable self-monitoring, attention to lifestyle changes, and major commitment and effort on the part of patients and clinicians, in addition to assuming that patients have the agency to produce change in this manner. Whereas they are powerful, these approaches require the development of controlled conscious processes that can be challenging to master and maintain for extended periods of time. More implicit, less effortful strategies to support these approaches might improve outcomes.[17]

Behavior includes both intentional processes and processes that are activated without our full awareness.[18] Examples of many processes that can be activated outside of our awareness include self-regulatory processes activated with priming interventions[19] and conformance with normative behaviors when exposed to environmental cues.[20] Environmental cues also can activate habits, impulses, and goals.[21] Activating positive processes without engaging our reasoning capabilities can potentially support the more effortful work involved with conscious, intentional health behavior change.

Delay discounting (DD) is a self-regulatory process engaged without our full awareness in many of our day-to-day health-related decisions. DD rate is the rate at which humans and animals de-value a reward as a function of the time to receipt.[22,23] DD has shown robust generality and predictive validity with a wide variety of unhealthy behaviors including tobacco and other substance use, over-eating, risky sexual behaviors, management of diabetes, and even the use of sunscreen and seat belts[24-26] Bickel et al[25] summarize DD and health behavior omissions and commissions. Lower DD rates are associated with reductions in unhealthy behaviors, as well as more robust treatment responses.[27-33] DD rates also appear to be associated with a variety of sociodemographic characteristics and socioeconomic health disparities, although conclusions about the relationships between these factors and DD rates presently are tentative.[5] As such, DD has become a new therapeutic target in health behavior change.[34]

The role of DD in health-related decision-making is grounded in the Competing Neurobehavioral Decisions Systems (CNDS) Model, a dual-systems decision-making conceptualization of the psychological processes involved with making healthy, prudent, far-sighted choices in the context of immediately rewarding but less healthy choices.[34-36] The CNDS model identifies neurobehavioral and neuroeconomic mechanisms associated with decision-making and provides guidance for the development of interventions derived from the tenets of the model.[37] Broadly, the CNDS model posits that many health-related decisions are driven by the interaction between 2 functional neural networks: The executive function network, embodied in areas of the prefrontal cortex (PFC), values the long-term optimization of resources and governs self-regulatory processes such as future orientation, planning, and behavioral inhibition; the impulsive network, embodied in areas of the limbic and paralimbic regions of the brain, values immediate reward.[29,38-41] Many behavioral and neuroimaging studies support this model.[37,42] Activity in these neural networks reflects the attribution of value to immediate versus delayed reward.[34] Greater activity in areas of the PFC is associated with choosing more prudent, larger later rewards in the context of temptation[43] and lower delay discounting rates.[29,38-41]

Methods to decrease DD rates include cognitive interventions such as working memory training,[34] direct stimulation of the executive decision-making system.[44,45] and framing techniques intended to alter the temporal context in which decisions are made.[34] At this time, Episodic Future Thinking (EFT) tasks are probably the most developed framing techniques for reducing delay discounting.[46] EFT tasks require the development of EFT stimuli composed of positive, future events that will reasonably take place and that individuals anticipate, look forward to, and can vividly imagine in the future. Individuals are then exposed to these stimuli, written or auditory, on a schedule over a period of time. time.[47-51] Example: "In 6 months I will attend my daughter's wedding in my new dress." During EFT stimulus development, individuals are guided to imagine the situational and sensory details for

EFT stimuli until the vividness scores are ≥ 4 on a scale of 1-5 (1=very low, 5=very high). Vividness has been shown to predict the effectiveness of EFT to reduce discounting.[52] Although the development of the EFT stimuli is labor intensive, and some individuals are unable to attain vividness scores of ≥ 4, EFT tasks are shown to significantly activate brain regions involved in future thinking, planning, and other executive functions,[52,53] decrease delay discounting rates, and tentatively improve cigarette and calorie consumption.[48,51,54-56]

Priming is a framing technique in which cognitive stimulation of specific concepts, often below our awareness, influences behaviors in a predictable manner without engaging our reasoning capabilities.[18,57] Priming has been used widely to alter attitudes and behaviors,[58,59] including health behaviors,[60,61] but aspects of replicability are key.[62] Priming effects are influenced by psychosocial factors as well as social self-monitoring.[63,64] Although high social self-monitors may initially respond to priming stimuli in a manner consistent with the prime, they are less likely to maintain primed behaviors because they tend to shift behaviors to match social expectations.[63]

An initial investigation found that individuals randomized to an online Future Thinking Priming (FTP) task demonstrated significantly lower DD rates than those randomized to Present Focused and Neutral Priming (NP) tasks.[65] The effect sizes for this single exposure to FTP were similar to those found for single exposures to EFT. [50,51] If shown to be as effective as EFT at reducing DD rates and improving health behaviors, FTP has some significant advantages over EFT. All individuals are exposed to the same FTP stimuli. FTP stimuli do not need to be personalized or developed a priori with individuals and exposure to the FTP task requires little initial engagement outside of consent and reading the instructions. Additionally, whereas the effect of the FTP task on DD is dependent on the proportion of the task completed, it does not depend on imaginal vividness, which can be difficult to obtain and repeat for some individuals. Finally, the FTP task can be administered entirely with a structured online interface using multiple mobile devices. Ideally, individuals might, in the future, be matched with different DD interventions according to their needs and preferences, but the FTP task has the unique potential at this time to realistically be scaled-up in multiple public health and clinical settings with minimal resources.

In the present study, we aimed to replicate and extend the findings from the promising initial FTP study using a more rigorous pre/post-test control group design, a repeated measures analyses to account for baseline rates of discounting, and multiple DD measures and magnitudes. We recruited participants from Amazon Mechanical Turk (MTurk), an online worker platform. MTurk participants are reported to provide responses comparable to those of laboratory participants.[66-69] We hypothesized that the FTP would significantly decrease across all DD measures and commodities accounting for time and baseline rates of DD.

METHODS

Participants

English-speaking MTurk workers age ≥18 years who resided in North America were eligible to participate. Data were collected and analyzed in 2016. All participants provided informed consent.

Procedure

Participants (N = 2256) completed the baseline assessment and were sent a link 2 weeks later to complete the study. Once they clicked on the link they were randomized and completed the intervention and the outcome assessment. The FTP and NP tasks were used in the initial study.[65] These tasks were developed by experts in DD who systematically evaluated words and phrases that reflected a future or a neutral focus and were shown to decrease and have no effect on DD, respectively. The FTP stimuli were: "future," "self-discipline," "willpower," "discipline," "restraint," "self-control," "long-term," "save," "planned," and "investment." The NP stimuli were: "pale," "drab," "informative," "patriotic" "detached," "dispassionate," "middle of the road," "disinterested," "loud," and "formal." Instructions for the tasks emphasized key components by using bold characters, examples, and separate entries for all elements. Example: "You will need to use each word in the next step and you will not see this list again. Make sure you copy each word down on a piece of paper before you move forward." Participants were asked to write self-referential sentences

for each word followed by a self-referential paragraph with all the words: "In the next section, you will be asked to write a total of 10 different sentences describing yourself using the words in the list of words you just read and copied down. Each sentence needs to include at least one of the words on your list. Using pronouns like I, me, my, etc, be sure that each sentence uses the word describing yourself only (Example: if the word is "concerned" the sentence can be "I'm concerned about...." or if the word is "funny" the sentence can be "I'm not funny...." Example of an inappropriate sentence: if the word is proud the sentence should NOT be "My friends are proud…." because it describes your friends and not you). You will be presented with 1 box to write 1 distinct sentence. Upon completion of the first sentence, you will then click on the next box to write your next sentence until you have clicked through and completed each of your 10 distinct sentences." After submitting the sentences, participants were instructed to complete the paragraph writing activity: "Please use the 10 words given previously to write a short paragraph describing yourself. Please be sure to use the words to describe yourself only. Use each of the 10 words on your list in the paragraph. Like the sentences from the previous task, each of the words should specifically be used to describe yourself. The sentences in the paragraph must be different from the ones that you just wrote in the task above. Your paragraph should not exceed 1600 characters or no more than about 250 words." Participants received $1.80 after completing the baseline assessment and $2.20 after completing the intervention.

Measures

Demographic characteristics, collected at baseline, included age, sex, race, ethnicity, partnered status, educational level, household income, country, zip code, cigarettes per day, other forms of tobacco use, and number of alcoholic drinks per week. We assessed self-monitoring with the Self-Monitoring Scale, a 25-item instrument measuring the degree to which individuals conform to social influences. Statements include: "I find it hard to imitate the behavior of other people" to which participants respond either "True" or "False." Scores range from 0-25 with 0-8 interpreted as low, 9-14 as intermediate, and 15-25 as high self-monitoring.[70-72]

DD was the primary outcome and was assessed with 2 measures, the Monetary Choice Questionnaire (MCQ), medium magnitude[73]and the 5-Trial task, $100 magnitude.[74] The MCQ is a 27-item questionnaire in which participants are asked to choose between smaller rewards offered sooner and larger rewards offered later. Example: "Would you prefer $54 today, or $55 in 117 days?" The MCQ includes 3 sets of 9 items based on the magnitude of the reward (small - $35, medium - $60, or large - $85). The 27-item MCQ was embedded in a 60-item version of the instrument to reduce the carry-over effects from multiple administrations.[75,76] The 60-item MCQ included items that assess participant attention to the items. Example: "Would you rather have $30 today, or $45 today?"

The 5-Trial task is an interactive instrument that automatically adjusts to respondents' choices to produce a result after a maximum of 5 trials.[74] Respondents were asked on the first trial whether they would prefer $50 now or $100 in 3 weeks. If the immediate option is selected, then the second trial shortens the delay to one day ($50 now or $100 in one day). If the delayed option is selected on the first trial, then the second trial lengthens the delay (ie, $50 now or $100 in 2 years). Delays on all subsequent trials are adjusted based on responses from the preceding trial.

The outcomes from the MCQ and the 5-Trial task were expressed as the natural logarithm of k in Mazur's hyperbolic discounting model, with k increasing as the preference for smaller sooner rewards increases.[77] Lower k values mean that individuals are more willing to wait for a larger reward. For the medium magnitude MCQ, we also calculated an alternate scoring algorithm, proportionate choice which is the proportion of delayed versus total responses.[76]

Data Analysis

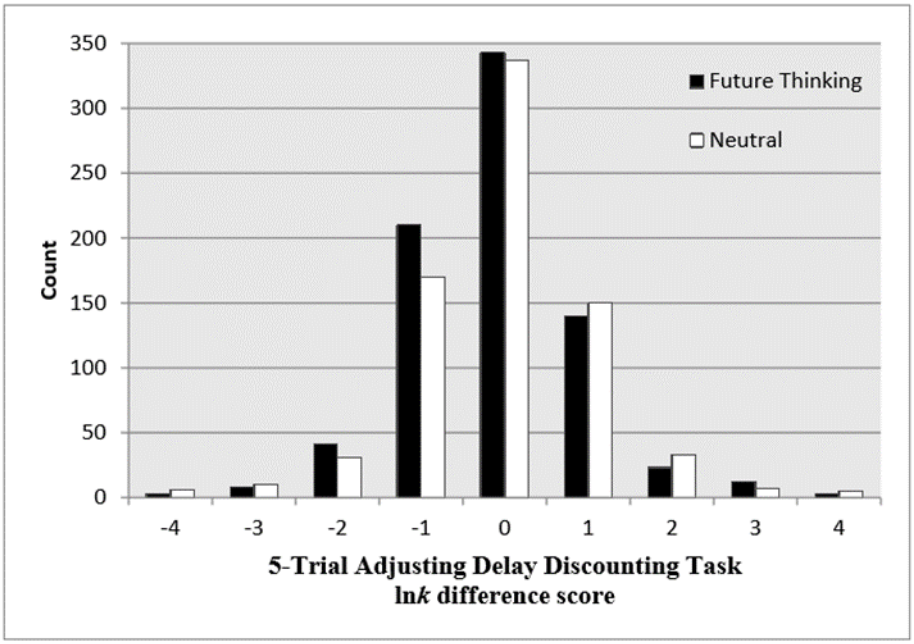
Analyses were carried out using IBM SPSS, Version 24 (Armonk, NY: IBM Corp). The natural log of k (lnk) was calculated to standardize the k parameters for the delayed discounting measures. With the traditional scoring of the MCQ, cases with inconsistent responses, consistency scores <.88, and answers that indicated non-attention to the participant attention items (N = 65) were excluded from the analyses.[41,78,79] For the 5-Trial task

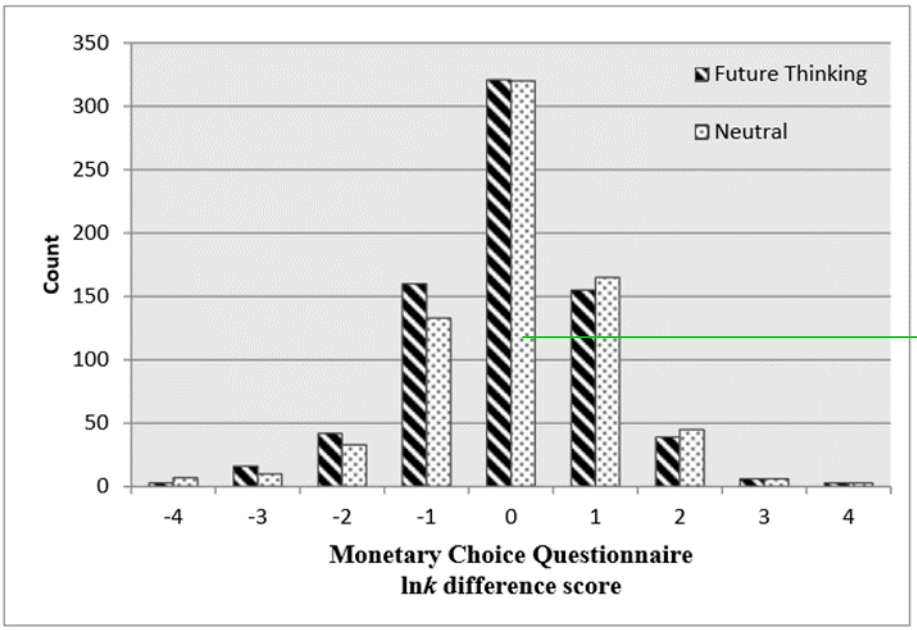
Table 1
Participant characteristics (N = 1532)

Characteristic / variable		Range, level, or category	Mean (SD) or percent (N)
Sociodemographic	Sex	Female	54.8 (840)
	Age	18-74	35.69 (11.26)
	Age categories	18-25	16.5 (253)
		26-31	28.6 (438)
		32-40	27.7 (425)
		41 and older	27.2 (416)
	Race	White	82.5 (1264)
		Black	6.3 (96)
		Asian	5.5 (84)
		Other	5.7 (88)
	Hispanic	Yes	6.5 (100)
	Partner status[a]	Partnered	58.7 (900)
	Education in years	1-28	15.55 (2.71)
	Education level	High school or less	17.2 (264)
		Attended college	65.9 (1010)
		Attended graduate school	16.8 (258)
	Annual household income	< $14,999	8.9 (136)
		$15,000-$24,999	10.7 (164)
		$25,000-$34,999	13.4 (206)
		$35,000-$49,999	16.9 (259)
		$50,000-$74,999	22.8 (349)
		$75,000-$99,000	13.0 (199)
		> $99,000	14.3 (219)
Alcohol and tobacco use	Alcoholic drinks per week	0-70	3.25 (5.99)
	Alcoholic drinks per week categories	0	38.3 (587)
		1-2	25.4 (390)
		3-5	20.0 (306)
		Greater than 5	16.3 (249)
	Cigarettes per day	0-50	2.48 (6.02)
	Cigarettes per day categories	0	78.3 (1199)
		1-4	5.0 (76)
		5-10	7.3 (112)
		11-20	8.3 (127)
		> 20	1.2 (18)
	Other tobacco use[b]	Yes*	12.7 (194)
Psychosocial	Self-monitoring scale	0-25	10.68 (4.68)
	Self-monitoring categories	Low	33.6 (515)
		Intermediate	44.5 (682)
		High	21.9 (335)

Note.
a: Un-partnered = single, divorced, separated, widowed; Partnered = (married or living with significant other).
b: Tobacco use other than cigarettes every day or almost every day such as hookah, cigars, cigarillos, e-cigarettes, vaporized nicotine, snuff, dip, orbs, sticks, etc.
*** More participants in the Future Thinking Priming condition reported other tobacco use than in the Neutral Priming condition (14.6% versus 10.7%; $\chi^2 = 5.21$, $p = .02$).**

Figure 1
Change in Delay Discounting lnk's Pre- and Post-intervention for the Future Thinking Priming and the Neutral Priming Conditions





Note.
Future Thinking Priming task demonstrates significant decreases in delay discounting assessed with 2 different measures, the 5-Trial Adjusting Delay Discounting Task and the Monetary Choice Questionnaire.

Table 2
Repeated Measures Analysis of Variance Model Results with Medium Magnitude MCQ lnk as the Delay Discounting Outcome Measure

Fixed Factors	Characteristics		Estimated marginal means (SE)	95% Confidence Interval		Partial eta squared
				Lower	Upper	
Condition	Neutral Priming task		-3.910 (.150)	-4.204	-3.615	$\eta^2 = 0.00$
	Future Thinking Priming task		-4.047 (.174)	-4.388	-3.706	
Time	Baseline		-3.969 (.120)	-4.204	-3.734	$\eta^2 = 0.00$
	Post-intervention		-3.988 (.122)	-4.226	-3.749	
Race**	White [a,b]		-4.430 (.058)	-4.544	-4.316	$\eta^2 = 0.02$
	Black [a,c]		-3.399 (.229)	-3.848	-2.950	
	Asian [c]		-4.478 (.313)	-5.091	-3.865	
	Other [d,b]		-3.606 (.240)	-4.076	-3.136	
Cigarette Smoking Status**	Non-smoker		-4.423 (.089)	-4.597	-4.249	$\eta^2 = 0.01$
	Smoker		-3.534 (.212)	-3.949	-3.119	
Time by Condition*	Neutral Priming task	Baseline	-3.972 (.156)	-4.279	-3.665	$\eta^2 = 0.05$
		Post-intervention	-3.848 (.159)	-4.160	-3.536	
	Future Thinking Priming task	Baseline	-3.966 (.181)	-4.321	-3.612	
		Post-intervention	-4.128 (.184)	-4.488	-3.767	

*** p < .05; ** p < .01**

Note.
a,b,c: Same superscript indicates location of differences at p < .05.
d: Multiple Races, American Indian, Alaska Native, Pacific Islander.
Partial eta squared effect size = small ~0.01, medium ~0.13, large ~0.26.

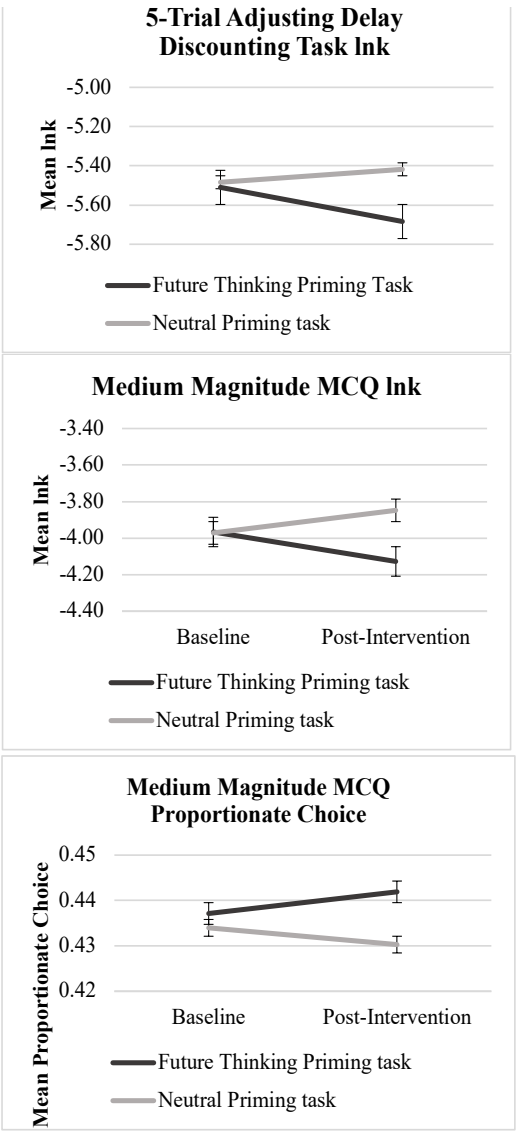
and the proportionate choice scoring of the MCQ all cases were included in the analyses.

Descriptive analyses were conducted to characterize participants (means, standard deviations, frequencies, etc). The FTP task was scored in the same manner as the initial study which showed high consistency among raters.[65] A trained research assistant awarded one point for correct use of each word in a sentence and in the paragraph for a total possible score of 20 points. Each word must have been used in a self-referential manner as per instructions. Points were not awarded for general statements or statements that referred to someone else. Example: "It is important to make an investment" or "My sister has a lot of willpower." A percent complete was calculated for each participant. The proportion of participants answering the attention items correctly was calculated. Statistical significance was set at alpha = .05.

One-way analysis of variance (ANOVA) and χ^2 analysis were used to examine the characteristic differences between participants randomized to the FTP and NP conditions. Pearson correlation analyses were conducted to examine relations between the lnk from the medium magnitude MCQ, the proportionate choice from the medium MCQ, and the lnk from the 5-Trial task. The DD lnk change scores were also calculated and plotted by condition to examine the relative distributions. Repeated measures ANOVA was used to account for baseline levels of DD as well as the role of demographic and psychosocial factors associated with priming and DD rates. Effect size (η^2 = partial eta-squared) is reported for all analyses (small ~.01, medium ~.13, large ~ .26).[80,81]

Model development was initiated by using separate univariate repeated measures analyses to examine the significance of individual factors including

Figure 2
Repeated Measures Analysis of Variance Model Results Including Estimated Marginal Means with Standard Errors: Future Thinking Priming Significantly Decreases Delay Discounting



Note.
Repeated measures analysis of variance model results (estimated marginal means with standard errors) with left to right: 5-Trial Adjusting Delay Discounting task lnk, medium magnitude MCQ lnk and medium magnitude MCQ proportionate choice as delay discounting outcome measures.

race, ethnicity, education, smoking status, cigarettes per day, other tobacco use, and self-monitoring; time; and condition for each of the 3 DD outcomes. The criterion for inclusion in the final model was a time by condition interaction p-value of < .10. In the final models, for each of the 3 DD outcome measures, we examined the effects of time, condition, the main effects of all of the retained variables, and all possible interactions.

RESULTS

Of 2256 participants who attempted the baseline assessment, 65 were removed from the analysis for inconsistent responses, and 666 did not complete the intervention leaving 1532 participants who completed both the baseline and intervention components and were included in the analyses unless otherwise noted. Participants' mean age was 35.7 years (SD 11.3); 54.8% were female; 98.2% lived in the United States (US) and 1.8% lived in Canada. The majority of participants were white (82.5%) and about half were partnered (58.7%). Two-thirds attended at least some college (65.9%). Annual household incomes ranged from < $10,000 (5.1%) to > $99,000 (14.3%). Over one-third did not drink alcohol (38.3%); 78.3% did not smoke cigarettes. The mean score for self-monitoring was intermediate (M = 10.7, SD = 4.7). No characteristic differences among participants randomized to the FTP and NP conditions were found with the exception of other tobacco use (FTP 14.6% vs NP 10.7%; $\chi^2 = 5.21$, p = .02). On average, participants took 24 minutes and 7 seconds to complete the intervention and the assessment instruments in the second half of the study (Table 1).

Participants completed a mean of 98.2% (SD = 7.75) of the sentences correctly and a mean of 95.6% (SD = 12.85) of the paragraphs correctly in the FTP task. For the MCQ, 95.4% of participants answered all attention questions correctly at baseline and 95.0% at follow-up. The Pearson correlation coefficients among the DD measures were highly correlated. Consistent with previous research, the MCQ lnk and the proportionate choice coefficient was r = - .99, p < .001.[65,76] The coefficient between the MCQ and the 5-Trial lnk's was r = .75, p < .001; between the MCQ proportionate choice and the 5-Trial lnk was r = -.76, p <

Table 3
Repeated Measures Analysis of Variance Model Results with 5-Trial Adjusting Delay Discounting Task lnk as the Delay Discounting Outcome Measure

Fixed Factors		Characteristics		Estimated marginal means (SE)	95% Confidence Interval		Partial eta squared
					Lower	Upper	
Condition		Neutral Priming task		-5.451 (.099)	-5.644	-5.258	$\eta^2 = 0.00$
		Future Thinking Priming task		-5.597 (.085)	-5.763	-5.431	
Time		Baseline		-5.497 (.066)	-5.627	-5.366	$\eta^2 = 0.00$
		Post-intervention		-5.551 (.071)	-5.690	-5.412	
Education*		Used as a covariate in the model		15.55 (.069)			$\eta^2 = 0.02$
Cigarettes per day**		Used as a covariate in the model		2.48(.154)			$\eta^2 = 0.02$
Other Tobacco Use		Uses other tobacco		-5.413 (.123)	-5.654	-5.172	$\eta^2 = 0.00$
		No other tobacco use		-5.635 (.045)	-5.724	-5.546	
Time x condition**		Neutral Priming task	Baseline	-5.484 (.100)	-5.680	-5.287	$\eta^2 = 0.05$
			Post-intervention	-5.418 (.107)	-5.628	-5.208	
		Future Thinking Priming task	Baseline	-5.510 (.086)	-5.678	-5.341	
			Post-intervention	-5.684 (.092)	-5.865	-5.504	
Time x condition x other tobacco use *	Uses other tobacco[a] (N = 194)	Neutral Priming task	Baseline	-5.388 (.190)	-5.761	-5.016	$\eta^2 = 0.03$
			Post-intervention	-5.203 (.203)	-5.601	-4.805	
		Future Thinking Priming task	Baseline	-5.410 (.160)	-5.723	-5.097	
			Post-intervention	-5.649 (.171)	-5.984	-5.315	
	No other tobacco use[a] (N = 1338)	Neutral Priming task	Baseline	-5.579 (.065)	-5.707	-5.451	
			Post-intervention	-5.634 (.070)	-5.770	-5.497	
		Future Thinking Priming task	Baseline	-5.609 (.065)	-5.737	-5.481	
			Post-intervention	-5.719 (.070)	-5.856	-5.582	

***p < .05, **p < .01**

Note.

a: Use of other forms of tobacco every day or almost every day. Other tobacco use includes hookah, cigars, cigarillos, e-cigarettes, vaporized nicotine, snuff, dip, orbs, sticks, etc. Partial eta squared effect size = small ~0.01, medium ~0.13, large ~0.26.

.001. The DD lnk change scores revealed a normal distribution of change scores among conditions for both DD measures (Figure 1).

Final Models

Monetary choice questionnaire. DD rates were significantly lower after the FTP task than after the NP task. The final model with the medium MCQ lnk as the outcome measure retained race and smoking status. This model revealed a statistically significant interaction between time and condition, F (1,1451) = 3.74, p = .05, η^2 = .05. The model also revealed significant main effects for race, F (1,1451) = 9.61, p < .001, η^2 = .02 and smoking status, F (1,1451) = 14.98, p < .001, η^2 = 0.01 and no main effects of time F (1,1451) = .07, p = .80 and condition F (1,1451) = .36, p = .55. No statistically significant interactions were observed between time and race, F (1,1451) = 1.69, p = .17; time and smoking status, F (1,1451) = .384, p = .54; time, condition and race, F (1,1451) = 1.821, p = .14; time, condition and smoking status, F (1,1451) = .77, p = .38; time, race and smoking

status, F (1,1451) = 1.13, p = .34 or time, condition, race and smoking status, F (1,1451) = 2.13, p = .10 (Figure 2 and Table 2).

The final model with medium MCQ proportionate choice (alternate scoring) as the outcome measure retained no demographic or psychosocial variables. The model revealed no marginal main effects for time F (1,1530) = .32, p = .57 and no main effect of condition F (1,1530) = .53, p = .47. Even though DD rates were significantly lower after the FTP task than the NP task, when baseline DD rates and time were including in the model, the interaction between time and condition was only marginally significant F (1,1530) = .32, p = .57) (Figure 2).

5-Trial adjusting delay discounting task. DD rates were significantly lower after the FTP task than the NP task. The final model with the 5-Trial task lnk as the outcome measure retained education, number of cigarettes per day, and other tobacco use. The model revealed significant main effects for education, F (1,1526) = 31.43, p < .001, η^2 = .02 and number of cigarettes per day, F (1,1526) = 31.56, p < .001, η^2 = 0.02 and no significant main effect for time, F (1,1526) = .53, p = .47, condition F (1,1526) = 1.28, p = .26, and other tobacco use, F (1,1526) = 2.85, p = .09. This model revealed a significant interaction between time and condition F (1,1526) = 7.98, p < .01, η^2 = .05 and between time, condition and other tobacco use, F (1,1526) = 4.71, p = .03, η^2 = 0.03. No statistically significant interactions were observed between time and education, F (1, 1526) = 1.10, p = .30; time and number of cigarettes per day, F (1, 1526) = .35, p = .56; and time and other tobacco use, F (1, 1526) = .419, p = .52 (Figure 2 and Table 3).

DISCUSSION

These findings demonstrate that a single administration of the FTP task reliably produces decreases in DD rates, at least in the short-term. These findings replicate and extend initial findings[65] and indicate that the intervention effect for a single administration is consistent across different monetary magnitudes and 2 DD measures. Because DD is strongly associated with multiple health behaviors, these findings support the examination of the effects of the FTP tasks on multiple health behaviors. The FTP tasks might complement more effortful approaches because the task is easily initiated and easily repeated. The task can be conveniently completed remotely using a computer or a mobile device. The task requires a minimal amount of time and does not require focus or awareness on targeted behavioral goals.

Although the patterns of the effects of the FTP task were similar between DD measures and magnitudes, the smaller magnitude medium MCQ produced larger discounting rates than the larger magnitude 5-Trial task (Figure 2). Consistent with previous findings, larger discounting rates are often found for smaller magnitudes because individuals require larger percent increases in value to compensate for delays of smaller amounts of money.[82,83] This contributes to confidence in the findings because it is consistent with how DD rates perform in other contexts.

These findings suggest the FTP task might obtain similar results to the EFT task, an implicit framing task which has concurrently decreased DD and positively altered health behaviors, at least short-term.[51,54] More research is needed to determine if the FTP task can positively alter health behaviors, and if so, to determine optimal frequency and exposure patterns to support durable changes in specific health behaviors alone and in combination with other interventions. Future research might also examine whether multiple administrations of both the FTP and the EFT tasks might show cumulative effects.

More research is needed to determine if different groups with different commonalities or characteristics such as race and socioeconomic status as well as different health behaviors such as smoking, healthful eating, physical activity, and substance use show different effect sizes. DD rates are likely to demonstrate ceiling effects for some groups (eg, substance users) especially for smaller magnitudes, so attention needs to be paid to rate dependency, commodities, and magnitude in the assessment of DD.[84,85] Determining the degree to which the impact of the FTP task depends on lawful, orderly rate-dependent relationships is also likely to identify specific priority groups for which the FTP task will be particularly effective or ineffective.[85-87]

Consistent with previous findings, we found some socio-demographic and tobacco use variables to have significant effects on the relation between

the FTP task and DD rate. Other studies have found DD rates to differ between ethnic, racial, and socioeconomic groups, supporting the contention that differences in DD might contribute to disparities in unhealthy behaviors;[5] however, stratified random samples are needed to indeed determine whether these important social groups demonstrate characteristic differences in DD rates. If so, the FTP task might, in the future, be adapted to increase its impact on different socio-demographic and other groups.

Limitations of this study include the characteristics of the sample. Although this sample was diverse in terms of biologic variables such as sex and age, and socio-demographic variables such as income, and educational level, the sample was composed of a higher proportion of Whites, non-Hispanic groups, and individuals with higher educational levels than the general population. Whereas the FTP tasks can be completed on any mobile device, which might increase generalizability to individuals without computers and computer literacy, these findings might be limited to individuals who are computer literate and have adequate reading and writing skills. Future research might adapt the task using imagery for low-literacy groups, should ensure more representation of racial and ethnic minority groups, and assess the device with which individuals engaged in the FTP tasks. Finally, the effect size also might be dependent upon the value that individuals place on a mainstream, western, middle-class future-oriented temporal orientation. Future research should assess temporal orientation as a cultural construct.

Whereas the FTP and the EFT effect sizes are similar, the FTP task is potentially more amenable to up-scaling, and thus, extending its reach and impact to multiple populations through broad dissemination, particularly among groups who experience significant challenges improving health behaviors. Repeated administrations of the FTP could become part of the services provided by state Quitlines and other public health programs through links sent by text or email. Quitlines reach about 1% of all US smokers per year, over 300,000 individuals annually. Similarly, the FTP could become part of the services provided to weight loss programs and part of the services offered to individuals through diabetes educators and other professionals who facilitate behavior change. Individuals might self-enroll through an online interface, similar to Text2Quit,[88,89] and receive links to the tasks through texts or emails. Similar priming stimuli might also be applied to develop public health messaging. Even if the effect size of these new strategies is small, the potential scalability of this intervention makes the potential public health impact significant.

IMPLICATIONS FOR HEALTH BEHAVIOR OR POLICY

Whereas important progress has been made in understanding and intervening with unhealthy and problematic health behaviors, health behavior change remains a significant public health challenge. Improving health behaviors such as tobacco use, energy imbalance, and illicit drug use are significant priorities for the World Health Organization and the Healthy People 2020 objectives.[3,4,90] DD has strong theoretical and bio-behavioral support as a novel therapeutic target for health behavior change. Interventions developed to target DD rate as a mechanism for health behavior change might serve to enhance and/or support evidence-based approaches. Priming is one of several approaches that have been popularly called "nudging," actions that alter choice architecture, often below awareness, in predictable ways without forbidding options or changing economic incentives.[91] The FTP task is one of several innovative strategies currently being studied with DD rate as therapeutic focus and supporting health behavior change as the ultimate goal.

The concept of changing a health behavior with small nudges over time that do not overtly engage reasoning capabilities is relatively new in terms of policy development, but industries have used nudging techniques that operate below individuals' awareness for a long time. For instance, to increase tobacco sales, the tobacco industry associates sex with product use, uses specific product placement strategies at point-of sale, and uses package color to convey a "healthier" cigarette choice.[92-96] Realistically, being nudged in an unhealthy direction is often how health behaviors go awry in the first place. For example, excess weight gain is not from one or 2 or even 10 or 20 big meals; excess weight gain results from a long series of contextualized de-

cisions about food and physical activity that forgo the prospect of future health for choices that meet an immediate need. Whereas there are now scores of studies that use priming to change health behaviors, there are no studies of which we are aware, that examine any priming techniques in terms of policy development and implementation.[97]

Nonetheless, this work has many implications for policymakers and practitioners. FTP, EFT, and other strategies that target DD to improve health behaviors represent options that are unlike straight-forward approaches like education and cognitive-behavioral approaches. Understanding the relationships among these strategies and DD rate and health behaviors might be a little obscure for patients, which raises ethical concerns about consent and personal autonomy. Also, from a social justice perspective, placing too much emphasis on individual change and agency has the potential to take away from the massive social and environmental determinants of health behaviors, especially for marginalized and economically disadvantaged groups. Ethically, policymakers and practitioners will need to consider whether the use of the FTP task is "justified manipulation" sometimes, especially if disseminated broadly, given that the effects are below one's awareness and do not overtly engage intention and reasoning. An appropriate and ethical manner for applying the FTP and similar strategies would empower individuals or communities to use the intervention intentionally and with full awareness of the expected outcomes. Policymakers, practitioners, and researchers need to address concerns about the consequences proactively when individuals' are not aware of what construct is being primed prior to implementation of these interventions in any contexts.

Although the current repertoire of health behavior theories represent decades of inspired research, there is considerable conceptual work to be accomplished to situate neuro-economic theories like the CNDS model and measures like DD within existing health behavior theory. Integration would conceivable develop a more comprehensive theoretical framework that accounts for both conscious internal factors, neuro-economic principles, and processes that are activated without our awareness. Such a theoretical framework would allow researchers to hypothesize about, explain, and predict relations among constructs such as motivation, self-efficacy, intention, and readiness, and delay discounting within a framework allowing for a robust examination. We see this as a significant challenge for theoretical researchers in the near future.

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Human Subjects Approval Statement

This study was approved by the Institutional Review Boards of City University of New York (#680011-1) and Roswell Park Comprehensive Cancer Center (#BDR082917). Informed consent was obtained from all participants.

Conflict of Interest Disclosure Statement

The authors have no conflicts of interests to declare.

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