

Contingency management effects on delay discounting among patients receiving smoking cessation treatment

Sara Weidberg¹, Reid D. Landes², Carla López-Núñez¹, Irene Pericot-Valverde¹, Alba González-Roz¹, Jin H. Yoon³ and Roberto Secades-Villa¹

¹ Universidad de Oviedo, ² University of Arkansas for Medical Sciences and ³ Baylor College of Medicine

Abstract

Background: Increasing evidence suggests that delay discounting may change following effective interventions. Nonetheless, previous studies that assessed the effect of contingency management (CM) on delay discounting are scarce, and their results are mixed. The current study assessed whether CM in conjunction with a cognitive-behavioral treatment (CBT) for smoking cessation was associated with changes in delay discounting at end-of-treatment and at 6-month follow-up compared to CBT alone. **Method:** One hundred and sixteen treatment-seeking smokers were randomly assigned either to CM + CBT (n = 69) or to CBT alone (n = 47). Participants completed delay discounting assessments at the intake, at end-of-treatment, and at 6-month follow-up. We evaluated CM's effect on discounting with parametric and nonparametric methods. **Results:** Between-group analyses showed that none of the interventions changed delay discounting from intake to end-of-treatment or to 6-month follow-up. Nonetheless, some within-group analyses showed that the CM + CBT condition evidenced some degree of reduction. **Conclusions:** The current results suggest that CM intervention is not robustly associated with delay discounting changes. Future studies should address treatments that may potentially change delay discounting.

Keywords: Delay discounting, smoking, contingency management, cognitive-behavioral treatment.

Resumen

Efectos del manejo de contingencias sobre el descuento por demora en pacientes que reciben tratamiento para dejar de fumar. Antecedentes: la evidencia sugiere que el descuento por demora puede cambiar tras recibir intervenciones eficaces. No obstante, estudios previos que evaluaron el efecto del manejo de contingencias (MC) sobre el descuento por demora son escasos y presentan resultados mixtos. Se evaluó si el MC combinado con tratamiento cognitivo-conductual (TCC) para dejar de fumar se asoció con cambios en el descuento por demora al final del tratamiento y a los seis de seguimiento comparado con TCC. **Método:** Ciento dieciséis fumadores fueron asignados aleatoriamente a MC+TCC (n = 69) o a TCC solo (n = 47). Completaron la tarea de descuento por demora en la línea base, al final del tratamiento y a los seis meses de seguimiento. Evaluamos el efecto del MC en el descuento por demora con métodos paramétricos y no paramétricos. **Resultados:** Los análisis entre-grupos mostraron que ninguno de los tratamientos modificó el descuento por demora al final del tratamiento y a los seis meses de seguimiento. No obstante, algunos análisis intra-grupos mostraron que la condición de MC + TCC evidenció cierta reducción. **Conclusiones:** una intervención de MC no se asocia robustamente con cambios en el descuento por demora. Futuros estudios han de abordar qué tratamientos pueden modificarlo.

Palabras clave: descuento por demora, tabaco, manejo de contingencias, tratamiento cognitivo-conductual.

Delay discounting describes the devaluation of a reinforcer as function of increasing delay to its receipt (Odum, 2011). Delay discounting has substantial relevance for understanding behavioral processes associated with a wide range of problematic behaviors, including substance use disorders (SUDs) (for reviews see Bickel, Koffarnus, Moody, & Wilson, 2014; Bickel & Marsch, 2001; Reynolds, 2006). Greater delay discounting is associated with earlier drug use onset (Audrain-McGovern et al., 2009; Ayduk et al., 2000), greater addiction severity (Cheng, Lu, Han, Gonzalez-Vallejo, & Sui, 2012; MacKillop et al., 2010; Ohmura, Takahashi,

& Kitamura, 2005; Reynolds, 2004; Rezvanfard, Ekhtiari, Mokri, Djavid, & Kaviani, 2010), and lower rates of abstinence both in laboratory models (Dallery & Raiff, 2007; Mueller et al., 2009) and clinical trials (MacKillop & Kahler, 2009; Sheffer et al., 2012; Stanger et al., 2012; Yoon et al., 2007). Also, greater discounting has been consistently observed among those with SUDs compared to matched controls across a wide variety of drugs of abuse (Baker, Johnson, & Bickel, 2003; Coffey, Gudleski, Saladin, & Brady, 2003; Dom, D'Haene, Hulstijn, & Sabbe, 2006; García-Rodríguez, Secades-Villa, Weidberg, & Yoon, 2013; Heil, Johnson, Higgins, & Bickel, 2006; Hoffman et al., 2006; Kirby & Petry, 2004; Odum, Madden, & Bickel, 2002; Petry, 2001).

Some correlational (Baker, et al., 2003; Takahashi, Furukawa, Miyakawa, Maesato, & Higuchi, 2007) and clinical studies (Black & Rosen, 2011) have observed that delay discounting is relatively stable over time among those with SUDs. Nonetheless, there is increasing evidence suggesting that delay discounting may change

Received: July 9, 2015 • Accepted: September 11, 2015

Corresponding author: Sara Weidberg

Facultad de Psicología

Universidad de Oviedo

33003 Oviedo (Spain)

e-mail: weidbergsara.uo@uniovi.es

under different pharmacological or environmental conditions (Dallery & Raiff, 2007; Koffarnus, Jarmolowicz, Mueller, & Bickel, 2013). For instance, increases in delay discounting have been observed following acute administration of alcohol among social drinkers (Reynolds, Richards, & de Wit, 2006). Likewise, increased discounting has been observed following acute deprivation of their drug of choice among cigarette smokers (Ashare & Hawk, 2012; Field, Santarcangelo, Sumnall, Goudie, & Cole, 2006; Mitchell, 2004; Yi & Landes, 2012) and opioid-dependent individuals (Giordano et al., 2002). Discounting rates also increased among pathological gamblers in gambling contexts (Dixon & Holton, 2009; Dixon, Jacobs, & Sanders, 2006).

Relatively few studies have examined the effect of clinical interventions on delay discounting among individuals with SUDs. Among those completed, decreased delay discounting has been observed following a working memory training procedure for stimulant-dependent individuals (Bickel, Yi, Landes, Hill, & Baxter, 2011) and a money-management intervention for cocaine- and/or alcohol-dependent individuals (Black & Rosen, 2011). The effects of contingency management (CM) on delay discounting have been mixed. Two studies showed that CM led to significant reductions in delay discounting rates among smokers (Yi et al., 2008) and opioid-dependent individuals receiving multimodal treatments of which CM was a part of each (Landes, Christensen, & Bickel, 2012), whereas no changes in delay discounting were observed among marijuana-dependent individuals receiving CM treatment (Peters, Petry, LaPaglia, Reynolds, & Carroll, 2013).

Taken together, these results suggest that delay discounting may change in response to effective CM treatment, but the limited number of studies makes further research necessary to confirm these findings (Bickel, et al., 2014). Also, whether changes in delay discounting persisted following termination of treatment is unknown, as previous studies only report end-of-treatment results.

The present study addresses this gap in the literature investigating whether CM in conjunction with cognitive-behavioral treatment (CBT) for smoking cessation was associated with changes in delay discounting at end-of-treatment and at 6-month follow-up. In this sense, previous research has showed that adding CM to CBT is effective for treating nicotine dependence. For instance, Secades-Villa, García-Rodríguez, López-Núñez, Alonso-Pérez, & Fernández-Hermida (2014) found that 95.3% of the smokers who received CM + CBT achieved abstinence after a 6-week treatment for smoking cessation, while only 59.2% of smokers who received CBT alone were abstinent at the end-of-treatment. Given that CM + CBT was more effective than CBT alone in order to promote abstinence, it is possible that this protocol could also lead to greater delay discounting changes. In the present study, potential delay discounting changes from intake to both end-of-treatment and 6-month follow-up were compared between participants who received CBT alone and those who received CM + CBT.

Method

Participants

Participants were 123 individuals seeking treatment for cigarette smoking at the Addictive Behaviors Clinic of the University of Oviedo (Spain). Inclusion criteria were as follows: being over 18 years old, smoking 10 or more cigarettes per day for the last

year and meeting criteria for nicotine dependence according to the Diagnostic and Statistical Manual of Mental Disorders (4th ed., text rev.; DSM-IV-TR) (American Psychiatric Association, 2000). Participants were excluded if they were diagnosed with a current psychiatric disorder (including substance use disorder besides nicotine dependence) or if they were receiving any other smoking cessation treatment. This study was approved by the Institutional Review Board of the University of Oviedo, and informed consent was obtained from all participants prior to study initiation. Seven participants (3 assigned to the CM + CBT condition and 4 assigned to the CBT condition) were excluded because they presented nonsystematic delay discounting data (Johnson & Bickel, 2008).

Eligible participants were randomly assigned to either the CM + CBT condition ($n = 69$) or CBT condition ($n = 47$). Table 1 shows the counts of participants who supplied delay discounting data at all the assessments (intake, end-of-treatment and 6-month follow-up) as well as those who missed one or more of these assessments. There were no significant differences between conditions in any sociodemographic and smoking-related variables (Table 2) or delay discounting rates at the intake (Table 3).

Instruments and variables

Sociodemographic (age, gender and marital status) and smoking-related [cigarettes per day, years of regular smoking, carbon monoxide (CO) and cotinine] characteristics were assessed

Table 1
Counts of participants who supplied delay discounting data for each group and assessment

	Intake only	Intake + end-of-treatment	Intake + 6-month follow-up	All three assessments	Total
CBT	1	6	1	39	47
CBT+CM	0	4	0	65	69
Total	1 ^a	10	1	104	116

Note: CBT = cognitive-behavioral treatment; CM = contingency management.
^a = Data from this participant is included in analyses that relate to inference on intake-only measures

Table 2
Participants' characteristics at intake

	CBT (n = 47)	CM + CBT (n = 69)	Statistic value	p value
Age (years) ^a	47.53 ± 11.27	43.36 ± 13.78	1.786 ¹	.077
Gender (% women)	55.3	66.7	1.085 ²	.298
Marital status (% married)	55.3	42	2.408 ³	.492
Cigarettes per day ^a	23.66 ± 9.41	20.52 ± 8.52	1.867 ¹	.064
Years of regular smoking ^a	27.48 ± 10.95	25.18 ± 13.40	0.967 ¹	.336
CO (ppm) ^a	16 ± 6.86	14.51 ± 5.99	1.242 ¹	.217
Cotinine (ng/ml) ^a	2,267.8 ± 1,110	2,424 ± 1,272	-0.619 ¹	.538

Note: CBT = cognitive-behavioral treatment; CM = contingency management; CO = carbon monoxide; ppm = parts per million; ng/ml = nanogram/milliliter.
^a = Means ± SD; Statistic used: ¹ Student's t; ² Yates' Continuity Correction; ³ Chi-squared

during the intake session, which lasted about 1 and a half hours. The Structured Clinical Interview (SCID-I) of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) (American Psychiatric Association, 2000) was used to assess nicotine dependence.

Smoking status was assessed at intake, end-of-treatment and 6-month follow-up. Participants provided a breath CO using a Micro Smokerlyzer (Bedfont Scientific Ltd., Rochester, UK). A BS-120 chemistry analyzer (Shenzhen Mindray Bio-medical Electronics, Co., Ltd., Shenzhen, P. R, China) was also used to assess urine cotinine levels. Self-reported smoking abstinence at the end-of-treatment and at 6-month follow-up was validated by presenting a breath CO level ≤ 4 ppm (Perkins, Karelitz, & Jao, 2013) and a cotinine test < 80 ng/ml. Agreement between the three measures was required to be categorized as abstinent. Participants were considered as smokers when they missed an assessment.

The delay discounting task was presented to participants at intake, end-of-treatment and 6-month follow-up via a laptop running the Windows Operating system. The task took approximately 10 minutes to complete for each participant. Participants were instructed how to interact with the delay discounting program and informed that they would not receive any of the monetary amounts presented, but they had to respond as if the choices were real. Participants were presented with a choice between €1,000 after a fixed delay versus various amounts of money available immediately using an adjusting-amounts procedure (Holt, Green, & Myerson, 2012). The delays values used were 1 day, 1 week, 1 month, 6 months, 1 year, 5 years and 25 years. The delays were

presented in an ascending order for all the participants. The value of the immediate monetary option ranged from €5 to €1,000 in €5 increments and was adjusted via a titrating procedure that honed in on the indifference point based on the participants' responses. The titration procedure took the lower and upper limit of possible values (initial €0 and €1,000) and divided this total range by 2, 3 or 4 to obtain an interval value. The value of the immediate option was one interval value above or below the upper and lower limits. If the immediate value was outside €0 and €1,000, another value was randomly chosen. New lower and upper limits were chosen based on the participant's response, adjusting the total range, and this titration procedure was repeated for each of the seven delays. Note that based on the possible values presented, the total values could occasionally increase if they chose an option outside of the total range. Once the total range was at or less than €40, the average of the upper and lower limits was taken as the indifference point, and the next delay was presented.

Treatment conditions

CBT

CBT consisted of a 6-week intervention described in previous studies (Becoña & Vázquez, 1997; Secades-Villa, Alonso-Perez, García-Rodríguez, & Fernández-Hermida, 2009; Secades-Villa, et al., 2014). CBT was implemented in group-based sessions of six patients. Each weekly session lasted about 1 hour. The components of the CBT were highly structured and included: information about tobacco, a behavioral contract, self-monitoring and graphical representation of cigarette smoking, nicotine fading, stimulus control, strategies for controlling nicotine withdrawal symptoms, physiological feedback consumption, training in alternative behaviors, social reinforcement of objectives completion and abstinence, and relapse prevention strategies. CO and cotinine specimens were collected twice a week. One of the measures coincided with the weekly CBT session and the other was scheduled midweek between sessions.

CM + CBT

The CM + CBT condition was similar to the CBT condition, but with the addition of CM. Participants were randomly assigned to two types of CM procedures: CM for smoking abstinence or CM for shaping abstinence. The CM for smoking abstinence included a voucher program in which nicotine abstinence was reinforced on an escalating schedule of reinforcement with a reset contingency. Points were earned for specimens testing negative for cotinine (< 80 ng/ml) from the fifth session forward (once the patients were required to be completely abstinent) (Secades-Villa, et al., 2014). The CM for shaping abstinence included a voucher program in which progressive reductions in cotinine (with abstinence also as final target) were reinforced according to an individualized percentile schedule. Points were earned for specimens that met the reduction criteria from the first session forward (Lamb, Kirby, Morral, Galbicka, & Iguchi, 2010; López-Núñez, Loredó-Martínez, Weidberg, Pericot-Valverde, Secades-Villa, 2015). Points were worth the equivalent to 1€ each. The maximum amount that patients could earn in both procedures was 300€. Points were exchangeable for vouchers with a variety of uses, including leisure activities, cinema, theater, museums, sport

Table 3

Summary statistics of AUC and $\ln(k)$ for each treatment condition and assessment period. Between-groups comparisons for each assessment period are also provided

Treatment condition	Assessment period	N	AUC		$\ln(k)$	
			Mean	Std Dev.	Mean	Std Dev.
CBT	Intake ^a	47	0.18	0.15	-4.29	2.78
	Intake	46	0.19	0.15	-4.34	2.79
	End-of-treatment	45	0.19	0.19	-4.32	2.79
	6-month follow-up	40	0.19	0.15	-4.29	2.93
CM+CBT	Intake	69	0.23	0.18	-5.01	2.68
	End-of-treatment	69	0.28	0.22	-5.45	2.72
	6-month follow-up	65	0.26	0.20	-5.68	2.15
CBT vs. CM+CBT	Assessment period		AUC		$\ln(k)$	
			$t_{(g)}$	p	$t_{(g)}$	p
	Intake ^a		-1.303 ₍₁₁₄₎	.195	1.399 ₍₁₁₄₎	.165
	Intake		1.198 ₍₁₁₃₎	.234	1.293 ₍₁₁₃₎	.199
	End-of-treatment		-2.320 ₍₁₁₂₎	.022	2.160 ₍₁₁₂₎	.033
	6-month follow-up		-1.994 ₍₁₀₂₎	.049	2.800 ₍₁₀₂₎	.006

Note: CBT = cognitive-behavioral treatment; CM = contingency management; AUC = Area Under the Curve; $\ln(k)$ = natural logarithm of k value

^aData including a participant who complete intake assessment only

events, gyms, adventure sports, meals in restaurants, training, purchases in department stores, and spa and beauty services (Secades-Villa, et al., 2014). In both procedures, participants were encouraged by therapists to consider spending their vouchers on goods and services that promote a healthier lifestyle. As no significant differences in abstinence rates between the two CM conditions were observed (López-Núñez, et al., 2015), data from the two conditions were combined for the current study.

Data analysis

We summarized the indifference points from each discounting task in two ways: area under the curve – AUC; and the natural logarithm of the hyperbolic *k* parameter – ln(*k*). Myerson, Green & Warusawitharana (2001) proposed AUC as an atheoretical discounting measure that avoids assumptions of any particular discounting model (Odum, 2011; Odum & Rainaud, 2003). AUC takes values from 1 (no discounting) to 0 (maximum discounting). For ln(*k*), we fitted the indifference points with a nonlinear regression model having the form of Mazur’s (1987) hyperbolic equation

$$E(Y) = 1/(1+\exp[\ln(k)D]), (1)$$

where E(*Y*) is the expected indifference point at delay *D*, given the subject discounts at rate $k = \exp[\ln(k)]$. We estimated ln(*k*) since the distribution of *k* across subjects tends to be approximately log-normal in distribution.

To measure within-individual change in discounting between intake and either end-of-treatment or 6-month follow-up, we took the difference. For example, AUC change at end-of-treatment was defined as intake AUC minus end-of-treatment AUC, and ln(*k*) change at 6-month follow-up as 6-month follow-up ln(*k*) minus intake ln(*k*). Computed as such, a negative difference indicates a decrease from intake discounting in both AUC and ln(*k*). We focus our analyses on the differences from intake discounting, and refer to these as d_{AUC} and d_{lnk} .

We analyzed both the d_{AUC} and d_{lnk} data in an analysis of variance (ANOVA) context having CM as a between-group factor, and both assessment period and CM × assessment period as within-group factors. Using the Bayesian information

criterion, we chose a compound symmetric covariance structure (equivalent to a first-order autoregressive structure) over an unstructured covariance. Kenward-Roger method (Arnau, Bendayan, Blanca, & Bono, 2014; Littell, Milliken, Stroup, Wolfinger, & Schabenberger, 2006) was used in order to estimate the error degrees of freedom.

Although a population may experience a mean significant decrease on delay discounting over time, individuals may deviate from this pattern by either not shifting at all, or shifting in the opposite direction. In order to assess whether each individual showed a statistically significant change in his or her delay discounting from one assessment period to another, we used the sign rank test described in Hadden (2012). This test uses the differences of indifference points paired on the delay from which they came while assuming no mathematical model of discounting. We tested whether each individual statistically changed from intake to both end-of-treatment and 6-month follow-up. We then used χ^2 tests to compare the CM groups for differences in the proportions of those statistically changing.

Primary analyses were conducted in SAS/STAT software, Version 9.3, SAS System for Windows (SAS Institute Inc., Cary, NC, USA), with linear mixed models fitted in the MIXED procedure. Confidence level was 95%.

Results

Delay discounting changes and treatment conditions

For each CM group and assessment period, Table 3 provides summary statistics of the delay discounting measures, and Table 4 the estimated change from intake discounting (*d*). Averaging over end-of-treatment and 6-month follow-up, change from intake discounting (*d*) did not significantly differ between the two treatment conditions, $F_{AUC}(1, 112) = 1.25, p = .267; F_{lnk}(1, 111) = 1.19, p = .278$; nor was there evidence of a CM × assessment period interaction, $F_{AUC}(1, 105) = 1.04, p = .310; F_{lnk}(1, 103) = 0.03, p = .874$. However, the CM + CBT group evidenced decreased discounting at both end-of-treatment, $t_{AUC}(154) = 2.34, p = .021; t_{lnk}(154) = 1.41, p = .160$, and 6-month follow-up, $t_{AUC}(160) = 1.67, p = .097; t_{lnk}(160) = 0.04, p = .032$; whereas CBT participants did not change their discounting neither at the end-of-treatment,

Table 4
Estimated mean change from Intake AUC and ln(k) with comparisons of CM groups added

Assessment period	Treatment condition	AUC			ln(k)		
		Mean	95% CI ^a	t-statistic	Mean	95% CI ^a	t-statistic
		Change ^a		&p-value	Change ^a		&p-value
End-of-treatment	CBT	-0.0	(-5.7, +5.6)	$t_{156}=0.00, p=.997$	+1.5	(-74.3, +77.4)	$t_{156}=0.04, p=.968$
	CBT+CM	-5.4	(-10.0, -0.8)	$t_{154}=2.34, p=.021$	-44.0	(-105.5, +17.5)	$t_{154}=1.41, p=.160$
	CBT vs. CBT+CM	-5.4	(-12.7, +1.9)	$t_{155}=1.47, p=.144$	45.6	(-143.2, +52.1)	$t_{155}=-0.92, p=.358$
6-month follow-up	CBT	-1.8	(-7.7, +4.0)	$t_{168}=0.62, p=.538$	-16.1	(-94.7, +62.6)	$t_{169}=-0.40, p=.688$
	CBT+CM	-3.9	(-8.6, +0.7)	$t_{160}=1.67, p=.097$	-68.7	(-131.3, -6.0)	$t_{160}=-0.04, p=.032$
	CBT vs. CBT+CM	-2.1	(-9.6, +5.4)	$t_{165}=0.56, p=.579$	-52.6	(-153.1, +47.9)	$t_{166}=-1.03, p=.303$

Note: CBT = cognitive-behavioral treatment; CM = contingency management; AUC = Area Under the Curve; ln(*k*) = natural logarithm of *k* value
^a = Actual AUC and ln(*k*) values have been multiplied by 100

$t_{AUC}(156) = 0.00, p = .997; t_{lnk}(156) = 0.04, p = .968$, or at 6-month follow-up, $t_{AUC}(168) = 0.62, p = .538; t_{lnk}(169) = 0.40, p = .688$. Averaged the change over the two time periods, change from intake discounting was significantly decreased in the CM + CBT group, $t_{AUC}(110) = 2.21, p = .029; t_{lnk}(108) = -1.99, p = .049$, but statistically unchanged in the CBT group, $t_{AUC}(114) = 0.35, p = .726; t_{lnk}(112) = -0.21, p = .836$.

Distributions of individually-based changes in delay discounting

Figures 1 and 2 show the proportions of participants who statistically decreased, experienced no significant change, or significantly increased their delay discounting rates as a function of treatment condition at the end-of-treatment and at 6-month follow-up, respectively. There were no significant differences between the two treatment conditions in these proportions either at end-of-treatment, $\chi^2_{(2)} = 0.090, p = .956$, or at 6-month follow-up, $\chi^2_{(2)} = 1.053, p = .591$.

The sign rank test showed that the rank correlation between these two assessment periods were 0.61 ($p < .001, n = 39$) for the CBT group and 0.62 ($p < .001, n = 65$) for the CM + CBT group. Results using $\ln(k)$ change measures were similar: correlations were 0.53 and 0.62 (both $p < .001$) for CBT and CM + CBT groups, respectively.

Abstinence outcomes

Abstinence rates are described in detail in a previous delay discounting study (Weidberg, Landes, García-Rodríguez, Yoon, & Secades-Villa, 2015). Effectiveness results showed that participants in the CM + CBT condition achieved higher rates of abstinence than those in the CBT condition at the end-of-treatment. Nonetheless, abstinence rates did not significantly differ between conditions at 6-month follow-up.

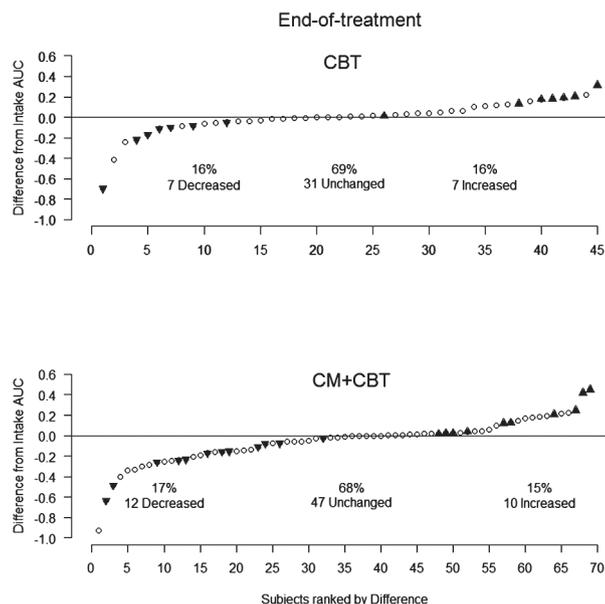


Figure 1. Within-individual change from intake AUC at end-of-treatment among the CBT and CM + CBT groups. Circles represent no statistical change; triangles statistical increase; inverted triangles statistical decrease

Discussion

The main purpose of the present study was to assess whether CM added to a CBT intervention for smoking cessation was associated with changes in delay discounting at end-of-treatment and at 6-month follow-up. There are three noteworthy outcomes of the current study: (a) between-group analyses showed no statistical differences among treatment conditions; (b) within-group analyses showed that participants in the CM + CBT condition evidenced some degree of discounting decrease that depended on the measure of discounting used; participants in the CBT condition failed to show no statistical change across time; and (c) distributions of individually-based changes in delay discounting were similar in both treatment conditions.

The vast majority of the analyses conducted showed that neither the CBT nor the CM + CBT interventions changed delay discounting from intake to both end-of-treatment and 6-month follow-up. Similar results were found in a previous work from Peters et al. (2013), who showed that marijuana dependents did not change their discounting after receiving a 12-week CM treatment, either alone or combined with CBT. Nonetheless, this previous study showed that participants who received CBT alone increased their discounting from intake to end-of-treatment, while in the present study participants who received CBT alone did not statistically change their discounting across time. It is possible that only specific treatments, such as those that directly target executive functioning (see Bickel et al., 2011) or psychopharmacological approaches that use cognitive enhancers (Bickel, Jarmolowicz, Mueller, Koffarnus, & Gatchalian, 2012) are effective to reduce delay discounting. Future research should also assess which treatments or combination of treatment components is most effective in order to reduce impulsive decision making (Bickel et al., 2012).

The within-groups reductions observed in some of the discounting measures among the CM + CBT condition may be

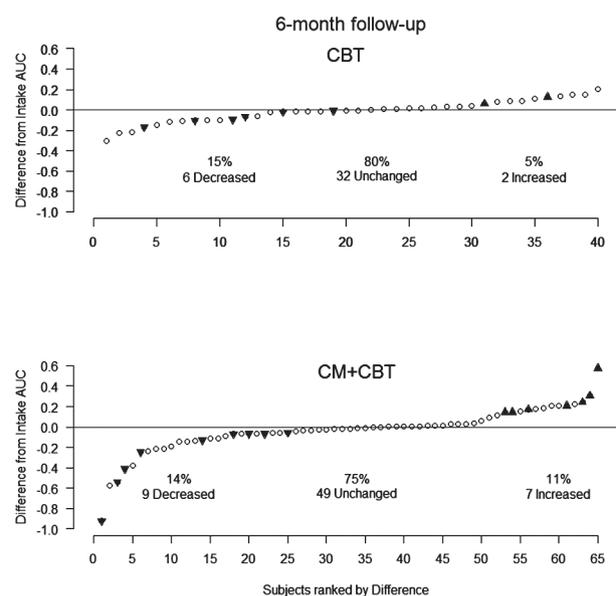


Figure 2. Within-individual change from intake AUC at 6-month follow-up among the CBT and CM + CBT groups. Circles represent no statistical change; triangles statistical increase; inverted triangles statistical decrease

primarily attributed to a more pronounced decrease in delay discounting at the individual level among participants who showed discounting reductions and received CM, compared to those participants who evidenced discounting reductions but did not receive CM. Factors such as immediate access to reinforcers for drug abstinence and the opportunity to consider spending vouchers on goods and services that promote a healthier lifestyle provided by CM (Chivers & Higgins, 2012; Higgins, Silverman, Sigmon, & Naito, 2012) may explain the significant decreases in delay discounting from intake levels among these specific individuals.

The present study has several limitations that point to future research lines. First, delay discounting rates were assessed using hypothetical monetary rewards and one may question whether the present findings would be similar as for discounting of real rewards. Nonetheless, previous research has found comparable results when hypothetical and real rewards are used (Baker, et al., 2003; Johnson & Bickel, 2002; Johnson, Bickel, & Baker, 2007; Lagorio & Madden, 2005; Madden, Begotka, Raiff, & Kastern, 2003; Madden et al., 2004). Second, there is a lack of statistical control of abstinence from smoking in the present study, which could affect the results found. Nevertheless, given that abstinence rates did not differ between treatment conditions at 6-month follow-up, abstinence is not expected to be a variable that could impact delay discounting in the present study. Third, this sample consisted of a particularly moderate dependent group of smokers. Future research should assess whether the present results can be

applicable to smokers with lower or greater levels of nicotine dependence. Future studies should also explore whether the current results can be generalized among individuals with other SUDs than nicotine dependence. Lastly, further research needs to be conducted to determine whether the present results are maintained with longer-term follow-ups.

Despite these limitations, our study shows that CM intervention did not appear to be robustly associated with delay discounting changes among a sample of treatment seeking adult smokers. Given the scarcity of studies that assessed whether any intervention, including CM, is related to delay discounting changes, more studies will be needed to confirm the present findings.

Acknowledgements

Funding for this study was provided by the Spanish Ministry of Science and Innovation (MICINN) Grant PSI2011-22804 and by three Predoctoral Grants, two of them from the Foundation for the Promotion of Applied Scientific Research and Technology in Asturias (FICYT) (BP11-031 and BP12-037) and the third one from the Spanish Ministry of Economy and Competitiveness (MINECO) (Ref. BES-2012-053988). The funding sources had no other role other than financial support.

All authors contributed in a significant way to the manuscript and have read and approved the final manuscript.

The authors report no conflicts of interest.

References

- American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders* (4th revised ed.). Washington, DC: American Psychiatric Association.
- Arnau, J., Bendant, R., Blanca, M. J., & Bono, R. (2014). The effect of skewness and kurtosis on the Kenward-Roger approximation when group distributions differ. *Psicothema*, *26*, 279-285.
- Ashare, R. L., & Hawk, L. W. (2012). Effects of smoking abstinence on impulsive behavior among smokers high and low in ADHD-like symptoms. *Psychopharmacology*, *219*, 537-547.
- Audrain-McGovern, J., Rodriguez, D., Epstein, L. H., Cuevas, J., Rodgers, K., & Wileyto, E. P. (2009). Does delay discounting play an etiological role in smoking or is it a consequence of smoking? *Drug and Alcohol Dependence*, *103*, 99-106.
- Ayduk, O., Mendoza-Denton, R., Mischel, W., Downey, G., Peake, P. K., & Rodriguez, M. (2000). Regulating the interpersonal self: Strategic self-regulation for coping with rejection sensitivity. *Journal of Personality and Social Psychology*, *79*, 776-792.
- Baker, F., Johnson, M. W., & Bickel, W. K. (2003). Delay Discounting in Current and Never-Before Cigarette Smokers: Similarities and Differences Across Commodity, Sign, and Magnitude. *Journal of Abnormal Psychology*, *112*, 382-392.
- Becoña, E., & Vázquez, F. L. (1997). Does using relapse prevention increase the efficacy of a program for smoking cessation? An empirical study. *Psychological Reports*, *81*, 291-296.
- Bickel, W. K., Jarmolowicz, D. P., Mueller, E. T., Koffarnus, M. N., & Gatchalian, K. M. (2012). Excessive discounting of delayed reinforcers as a trans-disease process contributing to addiction and other disease-related vulnerabilities: Emerging evidence. *Pharmacology & Therapeutics*, *134*, 287-297.
- Bickel, W. K., Koffarnus, M. N., Moody, N., & Wilson, A. G. (2014). The behavioral- and neuro-economic process of temporal discounting: A candidate behavioral marker of addiction. *Neuropharmacology*, *76*, 518-527.
- Bickel, W. K., & Marsch, L. A. (2001). Toward a behavioral economic understanding of drug dependence: delay discounting processes. *Addiction*, *96*, 73-86.
- Bickel, W. K., Yi, R., Landes, R. D., Hill, P. F., & Baxter, C. (2011). Remember the Future: Working Memory Training Decreases Delay Discounting Among Stimulant Addicts. *Biological Psychiatry*, *69*, 260-265.
- Black, A. C., & Rosen, M. I. (2011). A money management-based substance use treatment increases valuation of future rewards. *Addictive Behaviors*, *36*, 125-128.
- Coffey, S. F., Gudleski, G. D., Saladin, M. E., & Brady, K. T. (2003). Impulsivity and rapid discounting of delayed hypothetical rewards in cocaine-dependent individuals. *Experimental and Clinical Psychopharmacology*, *11*, 18-25.
- Chivers, L. L., & Higgins, S. T. (2012). Some Observations from Behavioral Economics for Consideration in Promoting Money Management among Those with Substance Use Disorders. *American Journal of Drug and Alcohol Abuse*, *38*, 8-19.
- Cheng, J. Q., Lu, Y. H., Han, X. D., Gonzalez-Vallejo, C., & Sui, N. (2012). Temporal Discounting in Heroin-Dependent Patients: No Sign Effect, Weaker Magnitude Effect, and the Relationship With Inhibitory Control. *Experimental and Clinical Psychopharmacology*, *20*, 400-409.
- Dallery, J., & Raiff, B. R. (2007). Delay discounting predicts cigarette smoking in a laboratory model of abstinence reinforcement. *Psychopharmacology (Berl)*, *190*, 485-496.
- Dixon, M. R., & Holton, B. (2009). Altering the magnitude of delay discounting by pathological gamblers. *Journal of Applied Behavior Analysis*, *42*, 269-275.
- Dixon, M. R., Jacobs, E. A., & Sanders, S. (2006). Contextual control of delay discounting by pathological gamblers. *Journal of Applied Behavior Analysis*, *39*, 413-422.

- Dom, G., D'Haene, P., Hulstijn, W., & Sabbe, B. (2006). Impulsivity in abstinent early- and late-onset alcoholics: differences in self-report measures and a discounting task. *Addiction, 101*, 50-59.
- Field, M., Santarcangelo, M., Sumnall, H., Goudie, A., & Cole, J. (2006). Delay discounting and the behavioural economics of cigarette purchases in smokers: the effects of nicotine deprivation. *Psychopharmacology (Berl)*, *186*, 255-263.
- García-Rodríguez, O., Secades-Villa, R., Weidberg, S., & Yoon, J. H. (2013). A systematic assessment of delay discounting in relation to cocaine and nicotine dependence. *Behavioural Processes, 99*, 100-105.
- Giordano, L. A., Bickel, W. K., Loewenstein, G., Jacobs, E. A., Marsch, L., & Badger, G. J. (2002). Mild opioid deprivation increases the degree that opioid-dependent outpatients discount delayed heroin and money. *Psychopharmacology, 163*, 174-182.
- Hadden, C. (2012). *Nonparametric Methods to Detect Within-Individual Changes in Discounting*. Little Rock, AR: Department of Biostatistics, University of Arkansas for Medical Sciences.
- Heil, S. H., Johnson, M. W., Higgins, S. T., & Bickel, W. K. (2006). Delay discounting in currently using and currently abstinent cocaine-dependent outpatients and non-drug-using matched controls. *Addictive Behaviors, 31*, 1290-1294.
- Higgins, S. T., Silverman, K., Sigmon, S. C., & Naito, N. A. (2012). Incentives and health: An introduction. *Preventive Medicine, 55*, S2-S6.
- Hoffman, W., Moore, M., Templin, R., McFarland, B., Hitzemann, R. J., & Mitchell, S. H. (2006). Neuropsychological function and delay discounting in methamphetamine-dependent individuals. *Psychopharmacology, 188*, 162-170.
- Holt, D. D., Green, L., & Myerson, J. (2012). Estimating the subjective value of future rewards: Comparison of adjusting-amount and adjusting-delay procedures. *Behavioural Processes, 90*, 302-310.
- Johnson, M. W., & Bickel, W. K. (2002). Within-subject comparison of real and hypothetical money rewards in delay discounting. *Journal of the Experimental Analysis of Behavior, 77*, 129-146.
- Johnson, M. W., & Bickel, W. K. (2008). An algorithm for identifying nonsystematic delay-discounting data. *Experimental and Clinical Psychopharmacology, 16*, 264-274.
- Johnson, M. W., Bickel, W. K., & Baker, F. (2007). Moderate drug use and delay discounting: A comparison of heavy, light, and never smokers. *Experimental and Clinical Psychopharmacology, 15*, 187-194.
- Kirby, K. N., & Petry, N. M. (2004). Heroin and cocaine abusers have higher discount rates for delayed rewards than alcoholics or non-drug-using controls. *Addiction, 99*, 461-471.
- Koffarnus, M. N., Jarmolowicz, D. P., Mueller, E. T., & Bickel, W. K. (2013). Changing delay discounting in the light of the competing neurobehavioral decision systems theory: a review. *Journal of the Experimental Analysis of Behavior, 99*, 32-57.
- Lagorio, C. H., & Madden, G. J. (2005). Delay discounting of real and hypothetical rewards III: Steady-state assessments, forced-choice trials, and all rewards. *Behavioural Processes, 69*, 173-187.
- Lamb, R. J., Kirby, K. C., Morral, A. R., Galbicka, G., & Iguchi, M. Y. (2010). Shaping Smoking Cessation in Hard-to-Treat Smokers. *Journal of Consulting and Clinical Psychology, 78*, 62-71.
- Landes, R. D., Christensen, D. R., & Bickel, W. K. (2012). Delay discounting decreases in those completing treatment for opioid dependence. *Experimental and Clinical Psychopharmacology, 20*, 302-309.
- Littell, R. C., Milliken, G. A., Stroup, W. W., Wolfinger, R. D., & Schabenberger, O. (2006). *SAS(r) for Mixed Models* (2nd ed.). Cary, NC: SAS Institute Inc.
- López-Núñez, C., Loredó-Martínez, V., Weidberg, S., Pericot-Valverde, I., & Secades-Villa, R. (2015). Voucher-based contingency management and in-treatment behaviors in smoking cessation treatment. *International Journal of Clinical and Health Psychology*. Advanced online publication. doi:10.1016/j.ijchp.2015.05.003
- MacKillop, J., & Kahler, C. W. (2009). Delayed reward discounting predicts treatment response for heavy drinkers receiving smoking cessation treatment. *Drug and Alcohol Dependence, 104*, 197-203.
- MacKillop, J., Miranda, R., Monti, P. M., Ray, L. A., Murphy, J. G., Rohsenow, D. J., et al. (2010). Alcohol Demand, Delayed Reward Discounting, and Craving in Relation to Drinking and Alcohol Use Disorders. *Journal of Abnormal Psychology, 119*, 106-114.
- Madden, G. J., Begotka, A. M., Raiff, B. R., & Kastern, L. L. (2003). Delay discounting of real and hypothetical rewards. *Experimental and Clinical Psychopharmacology, 11*, 139-145.
- Madden, G. J., Raiff, B. R., Lagorio, C. H., Begotka, A. M., Mueller, A. M., Hehli, D. J., et al. (2004). Delay Discounting of Potentially Real and Hypothetical Rewards: II. Between- and Within-Subject Comparisons. *Experimental and Clinical Psychopharmacology, 12*, 251-261.
- Mazur, J. E. (1987). An adjusting procedure for studying delayed reinforcement. In M. L. Commons, J. E. Mazur, J. A. Nevin & H. Rachlin (Eds.), *Quantitative analysis of behavior: The effects of delay and intervening events on reinforcement value*. (Vol. 55-73, pp. 88). Hillsdale, NJ: Erlbaum.
- Mitchell, S. H. (2004). Effects of short-term nicotine deprivation on decision-making: Delay, uncertainty and effort discounting. *Nicotine & Tobacco Research, 6*, 819-828.
- Mueller, E. T., Landes, R. D., Kowal, B. P., Yi, R., Stitzer, M. L., Burnett, C. A., et al. (2009). Delay of smoking gratification as a laboratory model of relapse: effects of incentives for not smoking, and relationship with measures of executive function. *Behavioural Pharmacology, 20*, 461-473.
- Myerson, J., Green, L., & Warusawitharana, M. (2001). Area under the curve as a measure of discounting. *Journal of the Experimental Analysis of Behavior, 76*, 235-243.
- Odum, A. L. (2011). Delay discounting: Trait variable? *Behavioural Processes, 87*, 1-9.
- Odum, A. L., Madden, G. J., & Bickel, W. K. (2002). Discounting of delayed health gains and losses by current, never- and ex-smokers of cigarettes. *Nicotine & Tobacco Research, 4*, 295-303.
- Odum, A. L., & Rainaud, C. P. (2003). Discounting of delayed hypothetical money, alcohol, and food. *Behavioural Processes, 64*, 305-313.
- Ohmura, Y., Takahashi, T., & Kitamura, N. (2005). Discounting delayed and probabilistic monetary gains and losses by smokers of cigarettes. *Psychopharmacology, 182*, 508-515.
- Perkins, K. A., Karelitz, J. L., & Jao, N. C. (2013). Optimal Carbon Monoxide Criteria to Confirm 24-hr Smoking Abstinence. *Nicotine & Tobacco Research, 15*, 978-982.
- Peters, E. N., Petry, N. M., LaPaglia, D. M., Reynolds, B., & Carroll, K. M. (2013). Delay Discounting in Adults Receiving Treatment for Marijuana Dependence. *Experimental and Clinical Psychopharmacology, 21*, 46-54.
- Petry, N. M. (2001). Delay discounting of money and alcohol in actively using alcoholics, currently abstinent alcoholics, and controls. *Psychopharmacology, 154*, 243-250.
- Reynolds, B. (2004). Do high rates of cigarette consumption increase delay discounting? A cross-sectional comparison of adolescent smokers and young-adult smokers and nonsmokers. *Behavioural Processes, 67*, 545-549.
- Reynolds, B. (2006). A review of delay-discounting research with humans: relations to drug use and gambling. *Behavioural Pharmacology, 17*, 651-667.
- Reynolds, B., Richards, J. B., & de Wit, H. (2006). Acute-alcohol effects on the Experiential Discounting Task (EDT) and a question-based measure of delay discounting. *Pharmacology Biochemistry and Behavior, 83*, 194-202.
- Rezvanfard, M., Ekhtiari, H., Mokri, A., Djavid, G. E., & Kaviani, H. (2010). Psychological and Behavioral Traits in Smokers and Their Relationship with Nicotine Dependence Level. *Archives of Iranian Medicine, 13*, 395-405.
- Secades-Villa, R., Alonso-Perez, F., Garcia-Rodríguez, O., & Fernández-Hermida, J. R. (2009). Effectiveness of three intensities of smoking cessation treatment in primary care. *Psychological Reports, 105*, 747-758.
- Secades-Villa, R., García-Rodríguez, O., López-Núñez, C., Alonso-Pérez, F., & Fernández-Hermida, J. (2014). Contingency management for smoking cessation among treatment-seeking patients in a community setting. *Drug and Alcohol Dependence, 140*, 63-68.
- Sheffer, C., MacKillop, J., McGeary, J., Landes, R., Carter, L., Yi, R., et al. (2012). Delay Discounting, Locus of Control, and Cognitive Impulsiveness Independently Predict Tobacco Dependence Treatment Outcomes in a Highly Dependent, Lower Socioeconomic Group of Smokers. *American Journal on Addictions, 21*, 221-232.
- Stanger, C., Ryan, S. R., Fu, H., Landes, R. D., Jones, B. A., Bickel, W. K., et al. (2012). Delay Discounting Predicts Adolescent Substance Abuse

- Treatment Outcome. *Experimental and Clinical Psychopharmacology*, 20, 205-212.
- Takahashi, T., Furukawa, A., Miyakawa, T., Maesato, H., & Higuchi, S. (2007). Two-month stability of hyperbolic discount rates for delayed monetary gains in abstinent inpatient alcoholics. *Neuroendocrinology Letters*, 28, 131-136.
- Weidberg, S., Landes, R. D., García - Rodríguez, O., Yoon, J. H., & Secades-Villa, R. (2015). Interaction Effect of Contingency Management and Sex on Delay-Discounting Changes Among Treatment-Seeking Smokers. *Experimental and Clinical Psychopharmacology*, 23, 361-368.
- Yi, R., Johnson, M. W., Giordano, L. A., Landes, R. D., Badger, G. J., & Bickel, W. K. (2008). The effects of reduced cigarette smoking on discounting future rewards: An initial evaluation. *The Psychological Record*, 58, 163-174.
- Yi, R., & Landes, R. D. (2012). Temporal and Probability Discounting by Cigarette Smokers Following Acute Smoking Abstinence. *Nicotine & Tobacco Research*, 14, 547-558.
- Yoon, J. H., Higgins, S. T., Heil, S., Sugarbaker, R. J., Thomas, C. S., & Badger, G. J. (2007). Delay discounting predicts postpartum relapse to cigarette smoking among pregnant women. *Experimental and Clinical Psychopharmacology*, 15, 176-186.