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Restricted psychological horizon in active methamphetamine users: future, past, probability, and social discounting

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Abstract

Methamphetamine users (MAU) exhibit an exaggerated bias for immediate rewards that reflects a restricted time horizon, where outcomes in the future are excessively discounted. An accumulating literature indicates that time in the future shares features with other dimensions of psychological distances including time in the past probability, and social distance, suggesting that bias for immediacy may be reducible to a more general restriction of psychological horizon. The purpose of the present study was to explore generalized restricted psychological horizon in active MAU by assessing future, past, probability, and social discounting. Compared with nonusing controls, MAU preferred psychologically proximal outcomes, resulting in higher rates for all types of discounting, which supports the conceptualization that MAU insufficiently integrate outcomes of psychological distance (i.e. in the future, the past, probabilistic, for others) into the valuation of current behavioral alternatives. The present results are suggestive of a more fundamental process of problematic decision-making associated with methamphetamine use, indicating the necessity of more comprehensive approaches to address the generalized limitations of restricted psychological horizon.

Keywords

behavioral economics; discounting; methamphetamine; psychological horizon

Introduction

The behavioral economic approach to the study of cross-temporal decision-making conceptualizes addiction as a disorder of restricted time horizon (Petry *et al*, 1998; Bickel *et al.*, 2006), where future consequences falling beyond the horizon (e.g. long-term negative consequences associated with drug use) are not adequately integrated into the valuation of

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Conflicts of interest

There are no conflicts of interest.

current behavioral alternatives. However, addiction is also characterized by memory deficits (Bechara and Martin, 2004; Rendell *et al.*, 2009), insensitivity to risk (Leland and Paulus, 2005; Feldstein and Miller, 2006), and social-cognitive dysfunction beyond generalized addiction-related social withdrawal (Homer *et al.*, 2008; Henry *et al.*, 2011; Kim *et al.*, 2011). Insights from basic research suggest that these addiction-related deficits may simply be different manifestations of a common underlying process.

Investigators across various domains of research (Buckner and Carroll, 2007) have commented on the relations and commonalities across dimensions of psychological distance such as time in the past and time in the future (e.g. Tulving, 1999) and time in the future and interpersonal distance (e.g. Dunbar, 1998; Rachlin, 2002). The Construal Level Theory (Trope and Liberman, 2003; 2010) directly addresses the identity of psychological distance dimensions, specifically theorizing that time in the future, time in the past, uncertainty, and social distance are dimensions reducible to a unitary psychological distance. Indeed, indications that addicted individuals differ from nonaddicted individuals in discounting as a function of psychological distance (across dimensions, indicating a generalized restricted psychological horizon) would have noteworthy theoretical significance for understanding addiction. Addiction would perhaps be better characterized as a disorder of restricted psychological horizon, where outcomes outside future, past, probabilistic, and interpersonal horizons do not or cannot influence decision-making. In other words, factors that can impact decision-making may be disproportionately anchored to outcomes with minimal psychological distance in addicted individuals, resulting from the discounting outcomes that are temporally delayed, occurred in the past, uncertain, or interpersonally distal.

Methamphetamine use and discounting

Chronic use of methamphetamine (MA) is associated with deficits of higher cognitive function (Nordahl *et al.*, 2003), and is known to impair function in brain areas, particularly the dorsolateral prefrontal cortex (Paulus *et al.*, 2002; Baicy and London, 2007), associated with valuation of outcomes along the dimensions of psychological distance noted here. With dorsolateral prefrontal cortex implicated in the discounting of future outcomes (McClure *et al.*, 2004, 2007; Hoffman *et al.*, 2008), dysregulation of this brain region may diminish probability of subsequent abstinence (elevated discounting of future outcomes predicts failed drug abstinence in the studies of Dallery and Raiff, 2007 and MacKillop and Kahler, 2009) and susceptibility to a host of other problematic behaviors associated with a restricted psychological horizon including risky sexual behavior (Chesson *et al.*, 2006; Iritani *et al.*, 2007; Springer *et al.*, 2007), crime and violence (Cohen *et al.*, 2003; Sommers *et al.*, 2006), anhedonia/mood problems (Hall *et al.*, 1996; Newton *et al.*, 2004), and psychosis (Snyder *et al.*, 1974). By assessing the reduction in the value (or impact) of outcomes as a function of the psychological distance to those outcomes, discounting procedures are properly suited to explore the relations between MA abuse/dependence and psychological horizon.

Of the various types of discounting, discounting of future outcomes has received the most attention in addiction research, probably because it provides a conceptual frame-work for understanding maladaptive behaviors that over-value present outcomes; a high rate of future discounting provides an explanation for why a drug user chooses the immediate satisfaction

of drug consumption over the larger, but delayed satisfaction of sobriety (e.g. better health). Research has largely supported this interpretation (Reynolds, 2006; Yi *et al.*, 2009b): individuals who abuse drugs (Madden *et al.*, 1997; Mitchell, 1999; Coffey *et al.*, 2003) and alcohol (Vuchinich and Simpson, 1998; Petry, 2001a) or have problems gambling (Petry, 2001b; Dixon *et al.*, 2003) discount future outcomes more than individuals who do not. However, studies of future discounting by methamphetamine users (MAU) are limited to those enrolling only abstinent or in-treatment MAU (Hoffman *et al.*, 2006; Monterosso *et al.*, 2007). Although this research has found elevated future discounting by MAU relative to nonusing controls (NUC), discounting by actively using, non-treatment-seeking MAU has yet to be examined – an important distinction given the influence of acute drug abstinence on future discounting measures (Giordano *et al.*, 2002; Field *et al.*, 2006; Yi and Landes, 2012). Furthermore, abstinent MAU or those seeking or receiving treatment may represent a qualitatively different subclass of MAU than those actively using MA and not seeking treatment.

Other types of discounting, specifically as a function of time in the past, probability, and social distance, have received much less attention in addiction research. We are aware of only one published study comparing a drug-using population (cigarette smokers) to NUC on measures of past discounting (elevated past discounting by smokers: Bickel *et al.*, 2008), a small handful of studies comparing these groups on discounting as a function of probability (generally mixed results: Mitchell, 1999; Reynolds *et al.*, 2004; Ohmura *et al.*, 2005; Yi *et al.*, 2007), and no published research comparing groups on discounting as a function of social distance.

Present study

Though future discounting by active users has been examined across many drugs of abuse (Yi *et al.*, 2009b), it has not been previously examined in active MAU. Furthermore, discounting by MAU as a function of the other dimensions of psychological distance (specifically time in the past, probability, and interpersonal distance) has not previously been examined. Thus, the present study addressed these gaps in the literature by comparing MAU to NUC on four types of discounting: future, past, probability, and social. If MAU have a generalized restricted psychological horizon, they should exhibit elevated rates across types of discounting, indicating preference for outcomes that are psychologically proximal (immediate or near immediate, certain, and for the self). Because previous discounting research has not comprehensively included these types of discounting, a secondary goal of the present study was to explore possible relations in the pattern of results across these types of discounting. Finally, questionnaire assessments ostensibly related to at least one type of discounting were included for exploratory purposes.

Methods

Participants

Participants were recruited through flyers, advertisements, and respondent-driven sampling (Heckathorn, 1997; 2002). Thirty MAU and 35 NUC, at least 18 years of age, completed study procedures. To accommodate the relative dearth of MAU who do not smoke tobacco

or marijuana (London *et al.*, 2004), we included cigarette and marijuana smokers while matching groups primarily on cigarette smoking status (the literature suggests that tobacco use is a more significant covariate; Mitchell, 1999; Johnson *et al.*, 2010). Secondly, groups were matched on demographic variables (sex, age, income, education) that have been found to covary with discounting (Green *et al.*, 1994; Kirby and Markovic, 1996; Kirby *et al.*, 2002; Jaroni *et al.*, 2004). A comprehensive semistructured interview was used to assess psychiatric, medical, and drug use histories. Psychiatric and medical assessments were self-report, and indications of significant psychiatric (e.g. axis I) or medical disorder resulted in discontinuation. Individuals meeting *Diagnostic and Statistical Manual of Mental Disorders, 4th ed.* (DSM-IV) criteria for other drugs dependence or exhibiting drug use in urinalysis that was not self-reported were also discontinued. Participants reported no current suicidality/homicidality, were not in the midst of significant life-altering events (e.g. job loss, divorce), and females were not pregnant.

Methamphetamine users—Participants self-reported MA as the primary drug of abuse, reported using MA at least weekly for a minimum of 1 year, and met DSM-IV criteria for amphetamine dependence. Biochemical support for self-reported MAU status was obtained using urinalysis (cutoff at 500ng/ml MA). Participants were not seeking treatment for MA use, and those seeking treatment were discontinued and referred to local treatment providers.

Nonusing controls—Control participants did not meet dependence criteria for MA and reported having never used amphetamines. Biochemical support for NUC status was obtained using urinalysis (absence of MA).

Procedures

All assessments were completed in one experimental session, except for instances where participants were unable to do so because of time constraints (two participants). The typical session duration was ~90 min. Following informed consent and screening, a urine sample was analyzed using a V-Twin Analyzer (Dade Behring Inc., Newark, Delaware, USA). Blood alcohol content was estimated using a breathalyzer (Alco-sensor, Intoximeters Inc., St Louis, Missouri, USA), and any value greater than 0.00 resulted in a discontinuation of the session.

Discounting procedures—Future, past, probability, and social discounting were assessed using computerized, binary choice procedures employing identical titrating algorithms (Green *et al.*, 1999; Holt *et al.*, 2003). Two hypothetical choice alternatives were presented on each trial, and participants were asked to choose as if the outcome were real. One alternative was an amount of money that was available immediately for the self; named the adjusting amount because the titration procedure adjusted this value trial-to-trial. The other alternative, referred to as the standard amount, depended on the magnitude condition: \$50 or \$10000. The standard amount was available at some point in the future (future discounting), had been available at some point in the past (past discounting), was available probabilistically (probability discounting), or was available for someone else (social discounting). Over six trials, the adjusting amount was titrated to determine the present, certain subjective value to the self of the standard amount (i.e. indifference point). Though

temporal discounting procedures typically employ 5–8 delays, our research suggests that discounting can be validly and reliably assessed using only three delays (Yi *et al.*, 2010). Given the high number of discounting conditions in the current study, we elected to use an abbreviated procedure, obtaining three indifference points for each magnitude/discounting type combination.

For all discounting assessments, the order of magnitude (\$50, \$10000) was counterbalanced between-subjects and constant within-subjects. Other than relevant semantic and syntactic changes unique to each discounting type, discounting procedures were identical.

Future discounting—Participants indicated preference between an adjusting amount that was immediate (\$X right away) and a standard amount that was in the future [wait (delay) and then receive \$Y]. Indifference points were obtained for \$50 and \$10000 at the following future delays: 1, 6 months, and 5 years.

Past discounting—The past discounting procedure was modeled on published procedures (Yi *et al.*, 2006; Bickel *et al.*, 2008). Participants indicated preference between an adjusting amount that was near immediate (having received \$X 1 h ago) and a standard amount that was in the distant past [having received \$Y (time in the past) ago]. Indifference points were obtained for \$50 and \$10000 at the following times in the past: 1 month, 6 months, and 5 years.

Probability discounting—Participants indicated preference between an adjusting amount that was certain (receive \$X for sure) and a standard amount that was probabilistic [(%) chance of receiving \$Y]. Indifference points for \$50 and \$10000 were obtained at the following probabilities of receiving the outcome: 75, 50, and 10%.

Social discounting—On the basis of the established procedure of Rachlin and Jones (2008), participants were asked to mentally rank order people that they knew according to subjective closeness (social distance) between 1 (closest) and 100 (farthest). Participants indicated preference between an adjusting amount for the self (\$X amount for you) and a standard amount for someone else (\$Y amount for *N*th person). Indifference points for \$50 and \$10000 were obtained at the following social distances: 5, 20, and 50. For instance, the subjective value of \$50 given to the fifth socially close person was determined for each participant.

Additional assessments

A battery of questionnaire assessments was included for exploratory purposes. These assessments are ostensibly related to discounting on at least one dimension of psychological distance, and were analyzed for possible relations with discounting; they were not meant to be comprehensive.

Delayed matching-to-sample task—Discounting may serve as a proxy for aspects of executive functioning (Bickel *et al.*, 2007) and past discounting may assess some component of memory functioning. Thus, a delayed matching-to-sample task (DMTS) may differentiate MAU and NUG. On a computer monitor, participants saw a target square (out of eight

possible squares differing in shades of gray) for 2 s. Following a delay of 0.5–20.0 s, participants matched the target square to one of four sample squares. The target square and the duration of the delay varied randomly for each trial, for a total of 128 trials. Each correct match earned 10 cents toward a fast food gift card.

Tasks I and II of the future time perspective (Wallace, 1956)—Future time perspective (FTP) and future discounting tasks have differentiated similar populations (Smart, 1968; Petry *et al.*, 1998; Hodgins and Engel, 2002), and may differentiate MAU and NUG. In task I, participants listed events they expect to occur to them in the future and when they expect that event to occur. Participants completed the back end of two stories in task II.

The Stanford Time Perspective inventory (Zimbardo, 1992)—The Stanford Time Perspective Inventory (STPI) addresses an individual's subjective time perspective, and may be related to discounting measures as well as differentiate MAU and NUC. The STPI is divided into five subscales: present-hedonic, present fatalistic, future-oriented, past-oriented, and time pressure. The first three subscales have been shown to differentiate heroin addicts from controls (Petry *et al.*, 1998).

Consideration of future consequences scale (Strathman et al., 1994)—This questionnaire evaluates the degree to which an individual considers consequences and evaluates time (like the STPI and FTP), and thus may differentiate MAU and NUC, and be related to discounting.

Social value orientation (Messick and McClintock, 1968)—Social value orientation (SVO) is assessed using the Decomposed Prisoner's Dilemma game, in which participants indicate preference for one of three alternatives. Each of the three alternatives allocates hypothetical sums of money to the participant and an unidentified other person, and represents choice consistent with a social motive: to maximize joint gain, to maximize personal gain, or to maximize relative gain. Participants were assigned one of the motives, and its corresponding SVO (prosocial, individualist, and competitor, respectively) if he/she made choices consistent with a particular motive in two-thirds of the total choice sets.

Adult Rejection Sensitivity Questionnaire (Downey and Feldman, 1996)—This 18-item questionnaire assesses an individual's sensitivity to rejection and inclination to interpret ambiguous information as rejection. Rejection sensitivity predicts interpersonal difficulties in children (Downey *et al.*, 1998), and may be related to social discounting.

Statistical method

Although a hyperbolic model (Mazur, 1987) is often favored when modeling discounting behavior, recent reports indicate that an exponential-power model may be preferable both theoretically (Killeen, 2009) and empirically (Yi *et al.*, 2009a). Thus, we used the exponential-power model [Eq. (1)] to determine discount rates in the current study, noting that discount rates are highly correlated across discounting models.

$$v_d = e^{-kt^2}, \quad (1)$$

where d represents temporal distance from the present (future and past discounting), odds-against (probability discounting; calculated as $[1-p]/p$) or social distance (social discounting). v_d represents the discounted value of an outcome and k represents the degree to which the value of a reward is discounted (discount rate). Higher values of k indicate greater discounting. Given typically skewed distributions of discount rates, parametric analyses were carried out using natural logarithm transformed k ($\ln-k$).

Because of personnel or computer error, the following data were not collected or lost: one participant – \$50 future, probability, and social discounting; one participant – \$50 future discounting. Data sets for the probability discounting of \$10000 did not converge for two participants. These instances were treated as missing data. For each type of discounting (future, past, probability, social), a 2 (group) $\times$ 2 (magnitude) analysis of covariance was conducted with marijuana status (a binary variable) and income included as covariates. Kenward–Roger’s method was used to calculate error degrees of freedom (Littell *et al.*, 2002). Save for interaction effects, we present t -statistics (noting that $F[1,d.f.e]=t^2[d.f.e.]$) because it is easier to determine relevant SE. In the presence of a significant interaction, follow-up tests were conducted to examine the comparison of interest at each level of the interacting factor.

Results

Groups were not significantly different in sex, age, years of education completed, and percent that smoke cigarettes (Table 1). Significant differences between groups were found in mean monthly income and percent testing positive for marijuana, and these variables were statistically accounted for in subsequent analyses.

Discounting

Analysis of future discounting replicated the ubiquitous magnitude effect, with the small magnitude discounted ($M = -0.97$) more than the large-magnitude reward ($M = -2.23$, $t[65.4] = 9.27$, $P < 0.001$). Across both magnitudes, MAU discounted future rewards ($M = -0.86$) more than NUC ($M = -2.35$, $t[65.7] = 4.85$, $P < 0.001$). There was a significant interaction between MA group and magnitude ($F[1,65.4] = 6.83$, $P < 0.02$), but the MAU discounted significantly more than NUC for both magnitudes (\$50: difference = 1.14, $t[60.8] = 3.99$, $P < 0.001$; and \$1000: difference = 1.85, $t[73.2] = 4.85$, $P < 0.001$; Fig. 1).

Past discounting data were consistent with future discounting, with the small magnitude discounted ($M = -1.23$) more than the large-magnitude reward ($M = -1.97$, $t[63] = 3.98$, $P < 0.001$), and MAU discounting past rewards ($M = -0.58$) more than NUC ($M = -2.62$, $t[62.8] = 4.58$, $P < 0.001$), with a significant group $\times$ magnitude interaction ($F[1,63] = 20.20$, $P < 0.001$). Follow-up tests revealed greater past discounting by MAU compared with NUC in both small ($t[61.7] = 2.77$, $P < 0.01$) and large magnitude conditions ($t[68.2] = 5.48$, $P < 0.001$).

The effect of magnitude on probability discounting data contrasted with future/past discounting; the large magnitude ($M = 1.18$) was discounted significantly more than the small magnitude ($M = 0.82$; $t[61.3] = 3.22$, $P < 0.005$). The comparison of MAU ($M = 1.44$) and NUC ($M = 0.55$) revealed a significant difference between groups ($t[62.6] = 3.05$, $P < 0.005$), with a significant group $\times$ magnitude interaction ($F[1,61.3] = 14.21$, $P < 0.001$). Follow-up tests revealed greater probability discounting by MAU compared with NUC in the large ($t[68.4] = 3.90$, $P < 0.001$) but not small ($t[61.7] = 1.65$, NS) magnitude conditions.

The large magnitude was significantly socially discounted ($M = -1.23$) more than the small magnitude ($M = -1.64$, $t[63.9] = 2.57$, $P < 0.02$). Across magnitude conditions, MAU ($M = -1.04$) socially discounted more than NUC ($M = -1.83$, $t[63.1] = 2.78$, $P < 0.01$), with no significant group $\times$ magnitude interaction ($F[1,63.9] = 0.80$, NS). Despite the lack of significant interaction, follow-up tests were conducted to maintain continuity with the analyses of other types of discounting; they revealed greater social discounting by MAU compared with NUC that reached significance in the small ($t[63.3] = 3.25$, $P < 0.005$) but fell just short of significance in the large ($t[71.1] = 1.80$, $P = 0.076$) magnitude conditions.

Other assessments

MAU and NUC were compared on the other assessments with independent groups t -tests (Table 2; χ^2 where appropriate). MAU had significantly higher means than NUC on Adult Rejection Sensitivity Questionnaire (ARSQ), FTP-mean extension, STPI present-hedonistic and present-fatalistic, and had significantly lower means on the consideration of future consequences scale (CFC) total score, STPI future-orientation and past-orientation. No significant differences were observed on the following: time-pressure subscale of the STPI, DMTS, SVO, and mean duration of FTP task II.

Relationship between dependent variables

Statistical corrections for multiple comparisons (e.g. Bonferroni's) would be overly conservative in the present case (Perneger, 1998). Recognizing that family-wise error is increased for individual correlations, we focus our results on identifying noteworthy patterns of relationships. Discounting parameters within type and across magnitudes were all highly and positively correlated (Table 3). Furthermore, future and past discounting were highly correlated, and they were both moderately correlated with social discounting. Future and past discounting were highly correlated with the CFC and numerous subscales of the STPI (Table 4) in the predicted directions. No significant correlations were observed between either SVO or DMTS and any measures of discounting, and these are not included in the table. Interestingly, only past discounting parameters were significantly correlated with the past-orientation subscale of the STPI, perhaps suggesting convergent validity on perception of the past and divergent validity on perception of the future. Probability and social discounting were generally not associated with these measures, though social discounting of \$50 was significantly correlated with the ARSQ.

Discussion

The present study compared MAU to NUC on measures of discounting as a function of the following dimensions of psychological distance: future, past, probability, and social distance. The study also explored the relationship between all four types of discounting, as well as between discounting and related questionnaire assessments. First, the effect of the magnitude conditions for each type of discounting is consistent with the established discounting literature. Specifically, the magnitude effect was observed in future and past discounting, and the reverse magnitude effect was observed in probability and social (nonsignificant) discounting (Estle *et al.*, 2006). Though secondary to the present study, consistency with the established literature on the magnitude effect enhances the credibility of the abbreviated discounting procedures, the use of the exponential-power discounting model, and the results of the group comparisons.

Second, MAU discounted future, past, probabilistic, and social outcomes more than NUC. Although previous research established higher future discounting by MAU in-treatment (Hoffman *et al.*, 2006) or following a period of abstinence (Monterosso *et al.*, 2007), the present study extends this finding to actively using MAU. Previous comparisons between smokers and nonsmokers on past discounting (Bickel *et al.*, 2008) is also extended to another drug of abuse; MAU appear not only to be present focused in relation to future outcomes, but to past outcomes as well, indicating that previous experiences are insufficiently incorporated into present and future behavior (as in the gambling task of Bechara and Damasio, 2002). The present results extend previous comparisons between smokers and nonsmokers on probability discounting (Reynolds *et al.*, 2004; Yi *et al.*, 2007) to MAU and NUC. MAU appear to prefer smaller, certain to larger, probabilistic rewards. Although this is inconsistent with a popular conceptualization of drug-dependent individuals as engaging in more risky behaviors (e.g. Feldstein and Miller, 2006), both generalized elevated risk-taking and higher rates of probability discounting are possible when conceptualized as insensitivity to risk (i.e. does not alter preference in response to variations in probability, treating high-probability events similar to low-probability events). More importantly, this result provides support for the conceptualization of MA use as reflecting restricted psychological distance that includes the dimension of probability. Finally, no published research has previously explored group differences in social discounting; the present results are the first to reveal elevated social discounting by an addicted population (MAU) compared with NUC, providing further support for the conceptualization of restricted psychological horizon as characteristic of addiction.

Third, exploratory assessments, specifically the CFC, FTP, and most subscales of the STPI, differentiated MAU and controls in the predicted directions. And fourth, correlations revealed: (a) significant relationships across magnitude within discounting type, (b) significant relationships between future and past discounting, (c) generally positive (some significant) correlations between all types of discounting, though it is noteworthy that social and probability discounting do not appear to covary, and (d) significant relationships between future/past discounting and questionnaire measures of how an individual thinks about time and the future. Specifically, individuals who focus on the present exhibited high rates of temporal (future and past) discounting, whereas those who focus on the future

exhibited low rates of temporal discounting. This suggests that while the included types of discounting may reflect dimensions of psychological distance, those assessments where time is the primary factor are uniquely related.

Group differences in future discounting, as well as the CFG, FTP, and STPI, provide support for the conceptualization that inadequate consideration of future outcomes (restricted time horizon; Petry *et al.*, 1998; Bickel *et al.*, 2006; Bickel and Yi, 2009) is a prominent factor that may contribute to the development, continuation, and consequence associated with MA dependence and other addictive behaviors. Moreover, the elevated rates of discounting observed in MAU across all types of discounting support the proposal that time in the future, time in the past, risk/probability, and social distance are dimensions of a common psychological distance (as proposed in the Construal Level Theory of Trope and Liberman, 2003; 2010) that is generally restricted in MA-dependent individuals. This relationship across dimensions of psychological distance has been similarly noted in Buckner and Carroll's (2007) conceptualization of self-projection, and relations between interpersonal and intertemporal decision-making (Read, 2001; Rachlin, 2002).

Despite this theoretically appealing explanation and the compelling overall pattern of discounting results, the support for the psychological horizon thesis is qualified: results were not identical across all discounting types, and not comprehensively correlated. This suggests that discounting processes for future and probabilistic outcomes (for example) are not identical; the contrary effects of magnitude provide ample evidence. Previous studies (Green *et al.*, 1999; Du *et al.*, 2002; Estle *et al.*, 2006) have also found that large-magnitude rewards are future discounted less (the magnitude effect, also observed in past discounting; Bickel *et al.*, 2008) but probabilistically discounted more (the reverse-magnitude effect) than small-magnitude rewards (also observed in social discounting; Rachlin and Jones, 2008). We emphasize that the distinction does not necessarily preclude the possibility of a common discounting process across dimension of psychological distance. One possibility is that probability discounting (for instance) requires the additional conversion of experienced relative frequencies into one-shot probabilities, and is thus subject to potential differences in decision weights (Kahneman and Tversky, 1979) as a function of the outcome magnitude. Indeed, despite some nonsignificant correlations across types of discounting, the common shape of future, past, probability, and social discounting functions appear to suggest, at minimum, overlapping processes. To date, few studies have examined a possible relationship between types of discounting, generally finding modest but significant positive correlations (Holt *et al.*, 2003; Myerson *et al.*, 2003; Reynolds *et al.*, 2004; Ohmura *et al.*, 2005; Bickel *et al.*, 2008), as in the present study.

Other limitations of the present study require consideration. Related to the previous issue, the degree of difference between the magnitude conditions could explain the incongruence observed in some discounting conditions. Choice in the large-magnitude condition (\$10000) is likely to be beyond the common or typical experience of most participants, and thus may be influenced by an underlying sense of fantasy. More broadly, it is perhaps this reality/fantasy distinction that is the underlying mechanism of the magnitude effect (an interpretation supported by the Construal Level Theory; Trope and Liberman, 2003). We

note, however, that even higher magnitudes have been used in previous discounting research (\$100000; Green *et al.*, 1999).

Another limitation includes the use of only hypothetical rewards. Although the published literature justifies the use of hypothetical outcomes (Madden *et al.*, 2003; Bickel *et al.*, 2009), different results for real rewards cannot be ruled out, particularly for past and social outcomes for which no real/hypothetical comparisons have been published to date. A fourth limitation is that use of tobacco and marijuana was assessed as binary variables (yes/no) rather than as more informative rate of consumption. Rate of tobacco consumption has been found to be positively correlated with temporal discounting (Ohmura *et al.*, 2005), and could have factored into the present results. A fifth limitation is related to the inclusion of only three indifference points for each discounting type/magnitude condition. Although the use of only three points is justified (Yi *et al.*, 2010), it may have resulted in a loss of sensitivity and an increase in the probability of type II error (i.e. loss of statistical power). Finally, the order of presentation of discounting types and the distances within those types were not counter-balanced. Although the expected effects of magnitude as well as other predicted effects suggest that the observed results are valid, we cannot rule out the impact of the fixed orders on the present rates of discounting.

Nonetheless., the present study indicates that non-treatment-seeking active MAU exhibited elevated future, past, probability, and social discounting compared with NUC. This result, combined with the pattern of statistical relationships between discounting indices (and between discounting indices and related questionnaire assessments), provides qualified support for the conceit that MAU have a restricted psychological horizon, manifest in inadequate integration of the value of psychologically distant outcomes of current behaviors such that factors falling outside this narrow window of influence cannot impact decision-making. This restricted psychological horizon may contribute to, or be influenced by, MA abuse/dependence. Although the present study examined active MA addiction as an exemplar of addiction in general, future research will address whether the observed similarities across types of discounting are maintained for other forms of addiction and drug dependence, that is specificity between and generality across MA use and other forms of addiction. Perhaps most significantly, further verification (or refutation) of this hypothesis can have significant impact on our theoretical understanding of addiction and have important implications for treatment interventions; addiction may reflect not only a failure to consider future consequences to current behaviors, but a general failure to consider factors outside of the here and now for the individual.

Significant clinical implications may follow from this more comprehensive perspective on psychological horizon. For instance, the full potential of intervention approaches for addiction may be limited if the underlying restriction of psychological horizon is not addressed as an aspect of treatment: aspects of cognitive-behavioral approaches may be requiring dynamic implementation of previously-learned, in-treatment skills and strategies in a population that insufficiently incorporates past learning into present behavior; aspects of group therapy and family systems approaches may be requiring awareness of the impact of personal behaviors on others in a population that insufficiently incorporates outcomes to others. Basic research informed by the psychological horizon construct (e.g. Fujita *et al.*,

2006; Schmeichel *et al.*, 2010) may offer innovative approaches to address decision-making deficits associated with addiction. More broadly, we believe that the present, interdisciplinary research offers a unique opportunity in which contemporary insights from other research domains inform the current understanding of addiction.

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Fig. 1.

For purposes of clarity, this figure indicates difference in discount rates ($\ln-k$) between methamphetamine users (MAU) and nonusing controls (NUC), calculated as $M_{\text{MAU}} - M_{\text{NUC}}$. All values are positive, indicating greater discounting by MAU compared with NUC. For each discounting type (future, past, probability, and social), MAU discounted significantly more than NUC when collapsed across magnitude conditions (main effects). Because of significant interactions, comparisons between MAU and NUC at each magnitude are presented separately within each discounting type; asterisks indicate statistical significance ($P < 0.05$) for each of these comparisons.

Table 1

Participant characteristics of methamphetamine users and nonusing controls

	MAU	NUC	<i>P</i> values
Sex (males, %)	60	60	1.00
Mean age	34.7	35.7	0.705
Education (completed)	12.40	12.74	0.334
Monthly income ^a	\$518	\$1160.70	0.017
Cigarette use (%)	73.3	57.1	0.179
Marijuana use ^a	50	8.5	0.0003

MAU, methamphetamine users; NUC, nonusing controls.

^aIncluded in subsequent analyses.

Table 2

Means of questionnaire and secondary assessments of methamphetamine users and nonusing controls

	MAU	NUC	<i>P</i>
ARSQ	10.68	8.69	0.046
CFC	32.23	42.37	<0.0001
FTP: mean extension	8.21	5.41	0.014
STPI			
Future-orientation	45.57	57.37	<0.0001
Past-orientation	23.87	26.54	0.016
Present-hedonistic	25.83	20.86	0.001
Present-fatalistic	25.37	18.74	<0.0001
Time-pressure	7.80	7.57	0.542
DMTS	39.36	41.51	0.19
SVO	0.48/0.35/0.17	0.66/0.22/0.12	0.39

ARSQ, Adult Rejection Sensitivity Questionnaire; CFC, consideration of future consequences; DMTS, delayed matching to sample; FTP, future time perspective; MAU, methamphetamine users; NUC, nonusing controls; STPI, Stanford Time Perspective Inventory; SVO, social value orientation (proportion that are prosocial/individualistic/competitive).

Table 3

Pearson correlations between discounting parameters

	Future \$50	Future \$10k	Past \$50	Past \$10k	Probability \$50	Probability \$10k	Social \$50
Future \$50							
Future \$10k	+0.76 [*]						
Past \$50	+0.44 ^{***}	+0.52 ^{***}					
Past \$10k	+0.62 ^{***}	+0.79 ^{***}	+0.68 ^{***}				
Probability \$50	+0.17	+0.23	+0.26 [*]	+0.16			
Probability \$10k	+0.35 [*]	+0.45 ^{***}	+0.16	+0.29 [*]	+0.71 ^{***}		
Social \$50	+0.48 ^{***}	+0.43 ^{***}	+0.31 [*]	+0.37 [*]	-0.01	+0.03	
Social \$10k	+0.17	+0.23	+0.16	+0.32 [*]	+0.05	+0.06	+0.48 ^{***}

* $P < 0.05$;*** $P < 0.001$.

Table 4

Pearson correlations between discounting parameters and questionnaires assessments

	STPI fut	STPI past	STPI pres-h	STPI pres-f	STPI time	CFC	ARSQ	FTP
Future \$50	-0.44**	-0.22	+0.36*	+0.49**	+0.09	-0.47**	+0.18	+0.27*
Future \$10k	-0.49**	-0.15	+0.41	+0.50**	-0.04	-0.49**	+0.19	+0.17
Past \$50	-0.41**	-0.28*	+0.25*	+0.25*	-0.19	-0.38*	+0.41**	-0.12
Past \$ 10k	-0.51**	-0.28*	+0.48**	+0.50**	-0.02	-0.55**	+0.30*	+0.16
Probability \$50	-0.19	-0.20	-0.03	-0.03	+0.13	-0.08	+0.07	-0.01
Probability \$ 10k	-0.28*	-0.09	+0.10	+0.12	+0.13	-0.23	-0.10	+0.07
Social \$50	-0.39*	-0.11	+0.23	+0.26*	-0.15	-0.30*	+0.36*	+0.08
Social \$10k	-0.23	-0.06	+0.22	+0.20	-0.04	-0.15	+0.18	-0.03

ARSQ, Adult Rejection Sensitivity Questionnaire; CFC, consideration of future consequences; FTP, future time perspective; STPI fut, future-orientation subscale; STPI past, past-orientation subscale; STPI pres-f, present-fatalistic subscale; STPI pres-h, present-hedonic subscale; STPI time, time pressure subscale.

* $P < 0.05$;

** $P < 0.001$.