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Alternate versions of a fixed-choice delay discounting assessment for repeated-measures designs

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Abstract

Delay discounting, reflected in the tendency to prefer immediate rewards over delayed rewards, is associated with most forms of problematic substance use. When assessed multiple times to examine within-individual changes, e.g., following acute drug administration or an intervention, shifts in delay discounting simply due to repeated assessment is a concern, particularly when the assessment task is identical. This may be true for the Monetary Choice Questionnaire (MCQ), a widely-used, fixed-item assessment of delay discounting. The present research examined possible within-individual difference/equivalence of MCQ indices at test/retest. This was contrasted with within-individual difference/equivalence when using an alternate version of the MCQ at retest, specifically developed to maintain the assessment structure and scoring of the original MCQ but with different choice items. Eighty-four participants completed delay discounting at test and retest with a 1-week interval; participants were randomized to complete the MCQ at both test and retest (MCQ/MCQ; $n = 43$) or complete the MCQ at test and an alternate version of the MCQ at retest (MCQ/MCQ-A; $n = 41$). Conventional hypothesis testing indicated no significant changes in delay discounting in the MCQ/MCQ condition nor MCQ/MCQ-A condition. However, equivalence analysis, which is able to establish whether scores are statistically equivalent, indicated that test/retest scores were not equivalent in some cases. Specifically, only one magnitude in the MCQ/MCQ condition was equivalent at test/retest, while two magnitudes in the MCQ/MCQ-A condition were equivalent at test/retest.

Keywords

delay discounting; Monetary Choice Questionnaire

Delay discounting (DD), reflected in the tendency to prefer immediate rewards over delayed rewards, has become an increasingly popular construct in human substance use research. DD has been extensively examined in human studies of addiction (MacKillop et al., 2011), with much of the work revealing group differences between those who misuse substances and those who do not (Yi et al., 2010) and a developing literature indicating its clinical relevance and utility (MacKillop & Kahler, 2009; Washio et al., 2011; Stanger et al., 2012).

There is emerging evidence that DD may change within-individual, with examination of DD changes resulting from acute substance administration (de Wit et al., 2002; Acheson & de Wit, 2008; Reynolds et al., 2006), intervention (Lee et al., 2015; Bickel et al., 2012; Dennhardt et al., 2015), or abstinence (Field et al., 2006; Yi & Landes, 2012; Ashare & Hawk, 2012; Miglin et al., 2017). Results across these studies are not always consistent, and it is becoming increasingly important that research implementing repeated assessments ensure that changes (or their absence) in DD are a result of experimentally-controlled intervening events rather than simply to repeated assessment.

Some basic research demonstrates that repeated assessment of DD using the same assessment may present challenges. In a study of different DD procedures (Weatherly et al., 2011), a significant decrease in DD was observed in the absence of any experimenter-controlled intervening event at 12-week retest. Similarly, test and retest of DD at 3 months by Ohmura and colleagues (Ohmura et al., 2006) revealed consistently lower indifference points (though DD rate was not significantly different) at retest. Given few studies explicitly showing no significant changes in DD rate as a function of repeated assessment, as well as many more that have not contrasted discount rates obtained in a repeated-measures design (e.g., Kirby, 2009; Simpson & Vuchinich, 2000), the possibility that repeated assessment of DFD alone results in a systematic shift in observed discount rate remains unanswered.

For the purpose of evaluating this question, as well as consideration of a repeated-measures strategy that may minimize the likelihood of such a possibility, we constrain our DD assessment to the Monetary Choice Questionnaire (MCQ). The MCQ is composed of binary-choice items, and benefits from the convenience of being a low-tech assessment that can be collected on a larger scale at low cost.

As exposure to the same items across multiple assessments could result in performance changes, we created an alternate but equivalent version of the MCQ inspired by the multiple equivalent versions of the Hopkins Verbal Learning Task (HVLT; Brandt, 1991), an assessment of verbal learning and memory. As with the equivalent version of the HVLT, we created an alternate MCQ while maintaining the same assessment structure; structural variation of DD tasks can result in different discount rates (e.g., Weatherly & Derenne, 2011). The present study examined the equivalence of discount rates when using the MCQ for both an initial and second assessment, compared to using an alternate version MCQ for the second assessment. Using a repeated-measures design, all participants completed the MCQ at time 1 and were randomized to complete either the same or alternate MCQ at time 2, one week later.

Method

Participants

One hundred fifty (150) Amazon Mechanical Turk (MTurk) workers in the United States were recruited online. Participants were native English speakers with a HIT (Human Intelligence Task) approval rate of 95% or higher. Of these participants, 66 failed to correctly answer attention check questions or complete both sessions of the study, and were excluded from all analyses. The remaining 84 participants (mean age = 33.1 years, 53.6% female) completed both sessions and their data were included in all analyses. All participants completed the MCQ at time 1, with 43 participants completing the same assessment and 41 participants completing the alternate version of the assessment at time 2. Participants were compensated \$2.00 for completing both sessions.

Materials

Monetary Choice Questionnaire (MCQ; Kirby & Marakovic, 1996, see Table 1)

—This 27-item, binary-choice assessment determines rate of DD. For each item, participants indicate preference for either a hypothetical amount of money that is delayed (larger-later, LL) or a smaller amount of money available immediately (smaller-sooner, SS). Nine choice items contribute to the calculation of a discount rate for each of small (\$25-\$35), medium (\$50-\$60), and large (\$75-\$85) magnitude rewards. The MCQ assumes the hyperbolic DD function (Mazur, 1987) $V_d = A / (1 + kD)$, where, V_d is the discounted subjective value of a delayed reward, A is the objective value of that outcome, D is the length of delay, and k is the index of delay discounting. Participants were instructed to think of the hypothetical money rewards as if they were real.

Monetary Choice Questionnaire-Alternate (MCQ-A, see Table 1)—We created an alternate version of the MCQ by taking each item of the MCQ and applying the following rules: (1) increase the value of the LL (i.e., A in the hyperbolic discounting function) by 10%, (2) increase the delay (D) to the LL by 10%, (3) keep the discount rate (k) constant, and (4) solve for the value of the SS (i.e., V_d). Money amounts were rounded to the nearest dollar and delays were rounded to the nearest full day. The resulting 27-item, binary choice questionnaire was identical to the MCQ in format and scoring, but with superficially different items (SS and LL).

Procedure

All participants completed the MCQ in session 1. After one week, participants were randomized to complete either the MCQ (43 participants in the MCQ/MCQ condition) or MCQ-A (41 participants in the MCQ/MCQ-A condition) in session 2. The study was approved by the University of Maryland Institutional Review Board (protocol # 868609-2; Assessing the reliability of money choice questionnaires).

Data Analysis

Rate of DD was calculated according to Kirby and Markovic (1996) and natural-logarithm transformed to normalize the distribution. Pearson Correlations of DD rates were calculated to assess the relative reliability of DD at times 1 and 2. Possible differences in DD at times 1

and 2 were examined using conventional hypothesis testing via $2 (\text{time}) \times 3 (\text{magnitude})$ analysis of variance (ANOVA), separately for the MCQ/MCQ and MCQ/MCQ-A conditions.

Equivalence tests were then conducted to examine statistical equivalence. Previous work (Matusiewicz et al., 2013), informed by guidelines from Welleck (2010), examined equivalence in assessment of DD, and we use the same procedure here. Specifically, equivalence was established if the following two criteria were met:

1. The $(1-\alpha) \times 100\%$ confidence interval (CI) for the difference in means must include 0 ($\log 1=0$); if $(1-\alpha) \times 100\%$ CI does not cover 0, it indicates that the two means are statistically different at the level of α .
2. The $(1-2\alpha) \times 100\%$ CI of the difference of the two means must fall within the equivalence region, defined as a ratio of the 2 means (i.e., $\text{mean1}/\text{mean2} = 4/5$ or 0.8 and the ratio's reciprocal (i.e., $\text{mean2}/\text{mean1} = 5/4$ or 1.25 (USDHHS, 2001).

We also examined intra-item consistency across time 1 and time 2. Indicated preference on each choice item at time 1 was compared to preference on the corresponding choice item at time 2. For these corresponding choice items, we dichotomized as consistent or inconsistent, and calculated proportion of consistency for each participant at each magnitude.

Results

As a substantial number of participants (66) completed session 1 but not session 2, comparison of delay discounting between those who did and did not complete session 2 was conducted. Mean rate of delay discounting was higher amongst participants who did not complete session 2 ($M=-4.77$) compared to participants who did complete session 2 ($M=-4.24$), though this difference was short of statistical significance ($p=.063$). Overall consistency measures (Kaplan et al., 2014) across items were high in sessions 1 ($M=97.06\%$), and 2 ($M=97.43\%$), for the MCQ ($M=96.66\%$) and MCQ-A ($M=98.19$) conditions in session 2, and none of the relevant contrasts indicated significant differences in consistency ($p>.05$).

Group demographics measures of MCQ/MCQ and MCQ/MCQ-A for participants included in all analyses were compared using independent sample t -tests on quantitative variables and χ^2 tests on qualitative variables. Groups were not different on demographics measures (all $p's>.112$), with the exception of education ($p=.049$). To examine education as a potentially important between-groups factor, bivariate correlations were conducted between all assessments of delay discounting and education. All correlations were low ($-.087 < r's < +.066$, all $p's>.431$), indicating no relation between education and DD, and education is considered no further.

Relative Reliability of DD

Rate of DD in the MCQ/MCQ condition at times 1 and 2 were strongly correlated ($r = +.819, +.791, +.852$, all $p < .001$) for small, medium, and large magnitudes, respectively. Similar results were found in the MCQ/MCQ-A condition, with high correlations at times 1 and 2 ($r = +.827, +.919, +.891$, all $p < .001$) for small, medium, and large magnitudes, respectively.

Conventional Hypothesis Testing

We examined changes in DD as a function of time in the MCQ/MCQ condition by performing a two-way (magnitude and time) ANOVA (Figure 1, top-left panel). The main effect of time ($F(1, 42) = 1.291$, $p = 0.262$) and the time $\times$ magnitude interaction ($F(2, 84) = .838$, $p = 0.436$) were non-significant. The main effect of magnitude was statistically significant ($F(2, 84) = 74.919$, $p < 0.0001$), with significant differences between all magnitude conditions (all $p < .001$) in post-hoc tests, replicating the ubiquitous magnitude effect.

We examined changes in DD as a function of time in the MCQ/MCQ-A condition with a separate two-way ANOVA (Figure 1, top-right panel). The main effect of time ($F(1, 40) = .115$, $p = 0.737$) and the time $\times$ magnitude interaction ($F(2, 80) = .973$, $p = 0.382$) were non-significant. The main effect of magnitude was statistically significant ($F(2, 80) = 23.767$, $p < 0.0001$), with significant differences between all magnitude conditions (all $p < .05$).

Equivalence Testing

To examine equivalence of DD in sessions 1 and 2, we compared rates separately for three magnitudes in MCQ/MCQ and MCQ/MCQ-A conditions. The bottom of Figure 1 presents the difference at times 1 and 2. The thick and thin horizontal bars represent 90% and 95% CIs, respectively, with each marked at the mean. The short- and long-dashed vertical lines refer to a value of 0 and the equivalence region ($-0.223, 0.223$), respectively.

With the exception of the medium magnitude in the MCQ/MCQ condition, all of the means fall within the equivalence region. Nonetheless, all 95% CIs overlap with 0, indicating that rate of DD were not statistically different between times 1 and 2. Thus, the first criterion for equivalence was met in both MCQ/MCQ and MCQ/MCQ-A conditions.

However, the 90% CI falls within the equivalence region for only the small magnitude in the MCQ/MCQ condition. In the MCQ/MCQ-A condition, the 90% CI fell within the equivalence region for both the medium and large magnitudes, but not for the small magnitude. Thus, the small magnitude in the MCQ/MCQ condition and the medium and large magnitudes in the MCQ/MCQ-A condition met the second criterion to establish statistical equivalence; the medium and large magnitudes in the MCQ/MCQ condition and the small magnitude in the MCQ/MCQ-A condition did not meet criterion to establish equivalence.

Item Consistency

We examined consistency on corresponding items of the DD assessment across times 1 and 2. Proportion of consistency within each magnitude was calculated as the frequency of

consistency (0-9) over the potential opportunities of consistency (9); proportion of consistency could range from 0.00 to 1.00, with increments of approximately 0.11. In MCQ/MCQ, median consistency for the small, medium, and large magnitudes were 0.89, 0.89, and 1.00, respectively. In MCQ/MCQ-A, median consistency for the small, medium, and large magnitudes were 1.00, 0.89, and 0.89, respectively.

Discussion

The first goal of the present study was to examine whether repeated assessment of DD resulted in statistically non-equivalent DD rates over a one-week interval. A second goal was to examine whether implementation of an alternate version of the DD assessment minimized this prospect. We examined test-retest difference/equivalence in DD via the MCQ as well as difference/equivalence when using an alternate but equivalent task for retest.

Conventional hypothesis tests indicated no significant difference when the MCQ was used at test-retest. This was true for the overall DD rate across all magnitude conditions, as well as for each magnitude condition separately. Conventional hypothesis tests also indicated no significant difference when the alternate version of the MCQ was used at retest, for the overall discount rate and for each magnitude separately.

Equivalence analyses then examined whether DD rate at retest was statistically equivalent to the initial test. Using the MCQ at test-retest resulted in equivalent rates of DD for one out of the three magnitude conditions. Similarly, using an alternate version of the MCQ at retest resulted in equivalent rates of DD for two out of the three magnitude conditions. Given an absence of any intervening event which should cause a systematic shift in DD, this suggests that using the alternate version of the MCQ at retest was slightly superior to using the MCQ for both test and retest.

These results do not indicate that repeated assessment of DD using the MCQ is invalid. Functionally, the changes in DD rate in both our MCQ/MCQ and MCQ/MCQ-A conditions were small, and the non-significant differences at times 1 and 2 indicate that observed changes in DD in previous research using repeated assessment via the MCQ are not likely due to repeated assessment. Moreover, the meaningfulness of establishing equivalence in 2 out of 3 magnitude conditions in the MCQ/MCQ-A condition compared to 1 out of 3 magnitude conditions in the MCQ/MCQ condition should not be overstated. Indeed, our item-consistency analysis indicates that participants remain largely consistent in choice across-time in both MCQ/MCQ and MCQ/MCQ-A conditions.

Limitations of this study are the constraints given the population, participant interface, and parameters selected for the study. MTurk workers using an online interface may represent a unique population, qualitatively different from the general population, thus limiting generalizability. Furthermore, there was a substantial (though non-significant) difference in session 1 delay discounting amongst recruited participants who did and did not complete session 2. The completion of the DD assessment via online, computer interface may also limit generalizability. And the duration between assessments at times 1 and 2 was one week for all participants, and we cannot rule out a different patterns of results for other durations

between assessments. We also cannot comment on possible difference/equivalence when DD is assessed more than twice. The selection of the MCQ as the DD assessment, despite its many advantages, may be limiting. For example, the MCQ does not result in the determination of indifference points that can be obtained using different discounting tasks; the results of the present study apply to the use of the MCQ and not to other DD tasks. A final consideration/limitation is the specific sample size obtained in the present study. Our obtained sample size for relevant within-subject comparisons was more than 46% larger than our previous efforts at establishing statistical equivalence of delay discounting (Matusiewicz et al., 2013). However, given the online platform for the present study, and even larger sample was possible, which could have resulted in a somewhat different pattern of results (e.g., statistical equivalence for all comparisons).

Despite these limitations, we believe the present study provides evidence that assessment of DD via MCQ repeated at a one-week interval are not statistically different, and in some instances, are statistically equivalent. The alternative version of the MCQ provides a valid alternative to retest using the same MCQ, and has the benefits of being procedurally and structurally similar, but with different binary choice stimuli. For investigators that are concerned about retest effects, particularly when the intra-assessment period is short (e.g., in laboratory studies), the MCQ-A represents a viable alternative to repeated use of the MCQ. Finally, this report provides a good statistical framework (equivalence test) for future studies that seek to establish statistical equivalence of DD.

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Public Significance Statement

This study examines scores obtained from an established paper and pencil assessment of delay discounting at a 1-week interval. An alternate version of the assessment provided comparable results, and could be implemented in instances where different assessment items are necessary or preferable.

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Figure 1.

Top panel - Mean of the log-transformed discounting rates for three magnitudes for each condition (MCQ/MCQ [left] and MCQ/MCQ-A [right]) and each time. The solid lines indicate time 1 and the dashed lines indicate time 2. Bottom panel - Difference of log-transformed discount rate (lnk) at times 1 and 2, for each magnitude and condition (MCQ/MCQ, MCQ/MCQ-A). Each line is marked at the mean. Thick bars represent 90% confidence intervals for the means, and thin bars represent 95% confidence intervals. The vertical long-dashed lines represent the equivalence region ($\log 0.8$, $\log 1.25$) = (-0.223, 0.223) and the short-dashed line represents $\log 1 = 0$.

Table 1

Items from the MCQ and MCQ-A

Magnitude	Question Order	MCQ				MCQ-A			
		SS Amount	LL Amount	Delay (days)	k	SS Amount	LL Amount	Delay (days)	
Small	13	\$34	\$35	186	.00016	\$38	\$39	205	
Small	20	\$28	\$30	179	.00040	\$31	\$33	197	
Small	26	\$22	\$25	136	.0010	\$24	\$28	150	
Small	22	\$25	\$30	80	.0025	\$27	\$33	88	
Small	3	\$19	\$25	53	.0060	\$21	\$28	58	
Small	18	\$24	\$35	29	.016	\$26	\$39	32	
Small	5	\$14	\$25	19	.041	\$15	\$28	21	
Small	7	\$15	\$35	13	.10	\$16	\$39	14	
Small	11	\$11	\$30	7	.25	\$11	\$33	8	
Medium	1	\$54	\$55	117	.00016	\$60	\$61	129	
Medium	6	\$47	\$50	160	.00040	\$51	\$55	176	
Medium	24	\$54	\$60	111	.0010	\$59	\$66	122	
Medium	16	\$49	\$60	89	.0025	\$53	\$66	98	
Medium	10	\$40	\$55	62	.0060	\$43	\$61	68	
Medium	21	\$34	\$50	30	.016	\$36	\$55	33	
Medium	14	\$27	\$50	21	.041	\$28	\$55	23	
Medium	8	\$25	\$60	14	.10	\$26	\$66	15	
Medium	27	\$20	\$55	7	.25	\$20	\$61	8	
Large	9	\$78	\$80	162	.00016	\$86	\$88	178	
Large	17	\$80	\$85	157	.00040	\$88	\$94	173	
Large	12	\$67	\$75	119	.0010	\$73	\$83	131	
Large	15	\$69	\$85	91	.0025	\$69	\$85	91	
Large	2	\$55	\$75	61	.0060	\$59	\$83	67	
Large	25	\$54	\$80	30	.016	\$58	\$88	33	
Large	23	\$41	\$75	20	.041	\$44	\$83	22	
Large	19	\$33	\$80	14	.10	\$35	\$88	15	
Large	4	\$31	\$85	7	.25	\$31	\$94	8	