Memory & Cognition (2021) 49:380–388
https://doi.org/10.3758/s13421-020-01088-4

# The impact of intrinsic and extrinsic features on delay discounting

**Achikam Cohen**[1] · **Sacha Bourgeois-Gironde**[2] · **Yehuda Pollak**[1]

Published online: 15 September 2020



## Abstract

Delay discounting refers to the tendency of people to evaluate immediate rewards as being more valuable than those that are distant in time. Several models explain this phenomenon by a set of intrinsic and extrinsic features. Intrinsic features are related to the inherent traits and neurological conditions of the individual, whereas extrinsic features are related to the characteristics of the reward. In this study, we refer to extraversion and attention-deficit/hyperactivity disorder symptoms (attention and hyperactivity-impulsivity) as intrinsic features, and to fungibility, perishability, and magnitude of the reward as extrinsic features. Whereas there is a known main effect to these intrinsic and extrinsic features, the current research examines their additive and interactive contributions to delay discounting. A total of 222 participants filled out an online questionnaire measuring intrinsic features and presenting decision tasks with different types of rewards. The scores of the intrinsic variables and the delay discounting rate for each reward were calculated and analyzed. The results replicated previous findings showing main effects of hyperactivity, fungibility, perishability, and magnitude. They also provided new findings on an interaction between fungibility-perishability and hyperactivity—the effect of hyperactivity on delay discounting was larger when the rewards were fungible and nonperishable than when the rewards were perishable and nonfungible. This interaction has practical implications that can help in moderating delay discounting in clinical treatments of impulsivity as well as in constructing efficient economic models for consumers.


**Keywords** Delay discounting · ADHD · Extraversion · Fungibility · Perishability · Magnitude

Delay discounting refers to the tendency of people to evaluate immediate rewards as being more valuable than those that are distant in time (Frederick, Loewenstein, & O'Donoghue, 2002). This tendency can be described as a hyperbolic function where the subjective value of a reward declines steeply with shorter delays, but more gradually with longer delays (Mazur, 1987). Specifically, according to Mazur's (1987) hyperbola, the discounting function is represented by the equation $V = \frac{A}{1+kD}$, where $V$ is the subjective value of the reward, $A$ is the future amount, $D$ is the delay, and $k$ is the discounting rate. Delay discounting procedures try to find the point at which two rewards, one relatively immediate but small and one large yet delayed, are approximately equal in value. This indifferent point could be further used to identify, measure, and predict personality traits and behaviors (Bickel, Odum, & Madden, 1999; Odum, 2011a, 2011b).

The correlation between delay discounting and maladaptive behaviors, including substance misuse, gambling, and obesity, has been studied extensively in the past decade (see Petry & Madden, 2010; Yi, Mitchell, & Bickel, 2010). In particular, steeper delay discounting has been consistently associated with attention-deficit/hyperactivity disorder (ADHD) in both children and adults (Jackson & MacKillop, 2016; Marx, Hacker, Yu, Cortese, & Sonuga-Barke, 2018; Patros et al., 2016; Scheres, Lee, & Sumiya, 2008). Delay discounting is also related to personality and other cognitive aspects, such as extraversion, impulsivity, and risk-taking (Green & Myerson, 2013; Odum, 2011a, 2011b). These findings suggest that delay discounting relates to typical and atypical behavioral profiles, and it is therefore the subject of growing interest to both psychological and economic research.

Behavioral economic models use delay discounting to explain the way that people view the trade-off between time and money. These models apply a utility function to quantify subjective values to understand consumer decisions (Sensation, 2013). The rewards are usually categorized as primary rewards

Sacha Bourgeois-Gironde and Yehuda Pollak contributed equally to this work.

✉ Achikam Cohen
achikam.cohen@mail.huji.ac.il

[1] The Seymour Fox School of Education, The Hebrew University of Jerusalem, Jerusalem, Israel

[2] Institut Jean Nicod, Département d'études cognitives, ENS, EHESS, CNRS, PSL University, UMR 8129, 29 rue d'Ulm, 75005 Paris, France

such as food, water, or sexual stimuli, and secondary rewards, such as money. Several studies in this field have found that monetary rewards are discounted more gradually than directly consumable rewards, such as food or drugs, despite the utility of the rewards being equal (Reuben, Sapienza, & Zingales, 2010; Tsukayama & Duckworth, 2010; Ubfal, 2016).

Neuroimaging research (McClure, Ericson, Laibson, Loewenstein, & Cohen, 2007; McClure, Laibson, Loewenstein, & Cohen, 2004) has shown that the limbic activity in the human brain applies a steep discounting function to the primary rewards, resulting from evolutionary pressures for physiological needs. Secondary rewards are context dependent, and therefore they exhibit more flexible discounting that is less sensitive to time. An alternative explanation for the mentioned results is that monetary rewards are generalized reinforcements. This means that since money is not a specific reward and can be exchanged for anything required or desired, its utility function is maintained (Estle, Green, Myerson, & Holt, 2007).

The research on delay discounting provides evidence for the influence of both intrinsic and extrinsic features. An intrinsic feature refers to the inherent traits and tendencies of the individuals (e.g., Odum, 2011a) and their neurological conditions (e.g., Madden & Bickel, 2010). Previous studies have shown that higher levels of extraversion elevate the discounting rate (Hirsh, Morisano, & Peterson, 2008). In addition, robust evidence has demonstrated that delay discounting is higher among individuals with ADHD compared with control subjects (Demurie, Roeyers, Baeyens, & Sonuga-Barke, 2012; Jackson & MacKillop, 2016; Patros et al., 2016; Scheres, et al., 2006). An extrinsic feature is related to the characteristics of the reward. Although an extrinsic feature does not belong to the individual's profile, it may influence the individual's behavior. For instance, fungibility, perishability, and magnitude features were found to influence the rate of discounting (Holt, Glodowski, Smits-Seemann, & Tiry, 2016).

Whereas many theories examine the discounting rate based on intrinsic or extrinsic features separately, research work on the relations and interactions between them is missing. The main purpose of the current study was to examine the interaction between intrinsic and extrinsic features to better understand the processes that drive delay discounting decisions. This was done using a hypothetical decision task, which was found to be a reliable substitute for real decision tasks (Madden, Begotka, Raiff, & Kastern, 2003).

In this study, we refer to extraversion, one of the Big Five traits, and ADHD symptoms, hyperactivity and inattention, as intrinsic attributes and assign individuals into groups according to them. Fungibility, perishability, and magnitude are defined as the extrinsic characteristics of the reward, and their level can be varied. We refer to fungibility as a feature that represents the ability of the individual to choose how to use the reward (e.g., restaurant voucher is more fungible than an order of sushi because one can select her or his favorite place and food to eat). Perishability is considered the amount of time one can consume the reward before it will be spoiled or lose value (e.g., food is more perishable than shoes). Magnitude is defined as the monetary value of the reward (e.g., a reward that costs \$500 has a higher level of magnitude than a reward that costs \$100). Note that changes in magnitude likely include changes in fungibility as larger magnitudes can be used to purchase more different items than smaller magnitudes.

Following previous work, we hypothesized that higher levels of extraversion elevate the discounting rate and that the delay discounting rate also increases among individuals with more symptoms of ADHD. In addition, we hypothesized that fungible, nonperishable, or high-value rewards would have a smaller delay discounting rate than would nonfungible, perishable, or low-value rewards, respectively. Whereas the individual hypotheses for intrinsic and extrinsic features were postulated, we did not have specific predictions regarding the additive and interactive effects between these features.

## Method

### Participants

The study was approved by the ethics committee of the Seymour Fox School of Education, the Hebrew University of Jerusalem.

The participants completed the study questionnaires and were paid \$2 for their participation using Amazon's Mechanical Turk (MTurk), a crowdsourcing platform (Buhrmester, Kwang, & Gosling, 2011; Goodman, Cryder, & Cheema, 2013). The survey was published in MTurk in six different batches that started on different days and hours, to allow for a diversity of the participants. The participants were identified by their MTurk ID and were required to fill in all questions to receive payment. The average completion time of the entire survey was 22.15 minutes ($SD$ = 12.34).

A total of 242 participants answered the survey, but 20 of them were excluded from the study before analyzing the data—10 because they answered the survey twice (so their second answer has been dropped), two completed it too fast (less than 5 minutes), and eight provided automatic answers (same answers in all the decision questions). This left a remaining total of 222 participants, 141 men and 81 women, with ages ranging from 18 to 64 years, where 50.45% of the sample are between the ages of 25 and 34. We assumed that most of the participants were from the U.S., based on the profiling of MTurk workers (e.g., Huff & Tingley, 2015). The level of their education varied, such that almost 25% graduated from high school, around 45% reported that they were undergraduates, 22% completed their college degree, and the rest (about 8%) had a higher level of education. Among the participants, 13% reported having a diagnosis of

ADHD. No regular use of medication was reported by 73% of the participants, 22% reported the use of medication not related to ADHD, and 5% reported taking medications that are used to treat ADHD, such as Adderall and Ritalin.

## Materials

The first part of the survey consisted of an informed consent form, describing the survey settings, including the goal of the survey, requirements, and payment. Next, a demographic questionnaire was used to collect general information on the participants, including age, gender, level of education and health status.

The intrinsic features were measured by two questionnaires: The Big Five Questionnaire and the ADHD Rating Scale Questionnaire. The Big Five Inventory (BFI) measured, in the current study, the five personality dimensions: openness to experience (Cronbach's $\alpha$ in the current study = .84), conscientiousness ($\alpha$ = .88), extraversion ($\alpha$ = .90), agreeableness ($\alpha$ = .84), and neuroticism ($\alpha$ = .90). Participants rated 44 items, consisting of short phrases, on a 5-point Likert scale (John, Donahue, & Kentle, 1991). The BFI has demonstrated reliability and validity across varied cultures and age groups (e.g., Denissen, Geenen, Van Aken, Gosling, & Potter, 2008).

The Adult Self-Report ADHD Rating Scale (ASRS) assesses ADHD symptoms in adults using 18-items on a 5-point Likert scale (Kessler et al., 2005; Pappas, 2006). The items directly relate to the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision* (2000; *DSM-IV-TR*) diagnostic criteria. The Hebrew version (ASRS-v1.1; Zohar & Konfortes, 2010) had good reliability ($\alpha$ = .89) and reasonable sensitivity (62.7%) and specificity (68%). For the current study, we used separate scales for inattention ($\alpha$ = .91) and hyperactivity/impulsivity ($\alpha$ = .90) symptoms rather than the combined scale ($\alpha$ = .94).

The delay discounting score was evaluated by an online delay discounting questionnaire (ODDQ) with various extrinsic features. In addition, we used the Quick Delay Questionnaire (QDQ) for validating the results retrieved from the ODDQ, ensuring that participants filled in the questionnaires consistently.

The QDQ questionnaire measures temporal discounting and delay aversion. It is a 10-item questionnaire using a 5-point Likert scale. The five ratings for each scale are averaged to create two measurements of delay aversion and delay discounting. Higher scores indicate higher delay aversion or temporal discounting (Clare, Helps, & Sonuga-Barke, 2010).

The ODDQ questionnaire is composed of a set of questions based on the five-trial adjusting method for delay discounting (Koffarnus & Bickel, 2014) and its implementation for Qualtrics® software (Koffarnus, Kaplan, & Stein, 2017). The adjusting method uses an algorithm to determine the amount of immediately available rewards that is delayed by seven discrete durations of time. At each delay, the participant has an option to choose between the delayed reward and half of the reward available immediately. Depending on the choice, the delay is adjusted. This process includes five trials, and the final result provides the indifferent point and the corresponding delay rate *k*. As an alternative, the method can provide the delay at which reward has lost 50% of its value, which enables one to calculate the area under the curve (AUC) as another measure of delay discounting (Yoon et al. 2017).

In our ODDQ questionnaire, the rewards differed in their magnitude, fungibility, and perishability, as described in Table 1. The rewards that valued approximately $100 included sushi roll combinations; bestselling books; a voucher for a meal in a Japanese restaurant; a gift card for books, toys, and electronics; and cash. Higher valued rewards, worth about $500, were chocolate candy bars and snacks; pairs of shoes; a voucher for buying food in a grocery store; a gift card for buying shoes and sports clothes; and cash.

## Procedure

The survey was published on the MTurk website and was accessible to every MTurk employee with high reliability (over 95% approval rate), who could review the survey before accepting it. The survey was administrated using a Qualtrics® system.

The participants were informed that the purpose of this study is a better understanding of the connection between personality and decision-making. They were asked to provide informed consent and then to answer the following questionnaires: demographic, BFI, ASRS, QDQ, and ODDQ. The order of the questionnaires was counterbalanced among the participants to prevent order effects. Each participant had an hour to complete the survey. After completing it, the answers were reviewed by the research team within a week. Participants who filled in the survey as required were paid for their time.

## Analytic approach

Using Qualtrics® capabilities, each response was captured and analyzed off-line based on automatic scores that were

**Table 1** Mapping of the rewards based on the extrinsic features

| | Magnitude | Perishable | Nonperishable |
|---|---|---|---|
| Nonfungible | Low ($100) | Sushi | Books |
| | High ($500) | Chocolate | Shoes |
| Fungible | Low ($100) | Restaurant voucher | Gift card for books |
| | High ($500) | Grocery voucher | Gift card for shoes |
| Very fungible | Low ($100) | | Cash |
| | High ($500) | | Cash |

assigned to each questionnaire. The results were then exported to Excel and SPSS, file and the final analysis was made by SPSS Version 25.0.

Descriptive statistics of the variables were calculated. The $k$ values were logarithmically transformed to form a normal distribution. The ODDQ was validated by correlating the mean $K_l$ ($MK_l$) and the QDQ scores.

The effects of the intrinsic features on the rate of delay discounting was tested through Pearson correlations and linear regressions. The effects of the extrinsic features and the interaction between the extrinsic and intrinsic features were tested by a set of analyses of variance (ANOVAs), with one of the intrinsic features as a within-subject independent variable, the extrinsic feature as a between-subject independent variable, and $k_l$ as the dependent variable.

## Results

### Descriptive statistics

The descriptive statistics of the variables ($N = 222$) are presented in Table 2. The intrinsic features were extracted from the BFI and ASRS questionnaires. The delay discounting rate $k$ that defines the average indifferent point was calculated for each reward based on the ODDQ questionnaire. We also measured delay discounting and delay aversion from QDQ to validate the data derived from ODDQ.

### Preliminary analyses

The $k$ values representing the individual delay discounting rate across the different rewards was not normally distributed (e.g., the skewness and kurtosis values for the mean $k$ were 3.44 ± .163 and 13.67 ± .325, respectively), and therefore we first transformed the values logarithmically (see Yi, Gatchalian, & Bickel, 2006), resulting in normally distributed values; the skewness and kurtosis values for the mean $k$ ($MK_l$) were .598 ± .163 and .310 ± .325, respectively. The individual $k_l$ values after the transformation were intercorrelated ($r$ is in a range of 0.25–0.67). The values of $k_l$ after the transformation were negative, but still captured the idea that a bigger $k_l$ means a steeper delay discounting rate. AUCs were calculated and log transformed. The correlation between $MK_l$ and the mean AUC was very high ($r = .984$), and the results of all the analyses were about the same regardless of the specific measure. For the sake of brevity, we present only the analyses concerning $k$ as the dependent measure.

To validate our results from the ODDQ, which are used throughout this experiment, we examined the correlation between the arithmetic mean $MK_l$ and QDQ measures. We found a correlation between delay discounting and delay aversion ($r = .61$, $p < .01$), $MK_l$ and delay discounting ($r = .38$, $p < .01$), and $MK_l$ and delay aversion ($r = .17$, $p = .01$). These correlations suggest that our variables $k_l$ are ecologically valid measures of delay discounting.

### Impact of intrinsic features on delay discounting

We examined the first hypothesis that higher levels of extraversion elevate the discounting rate, and that delay discounting rate also increases among individuals with more symptoms of ADHD. In a correlation test of BFI measures (extraversion, openness, agreeableness, conscientiousness, and neuroticism) with $MK_l$ , extraversion, agreeableness, and conscientiousness were found to be correlated with $MK_l$, as shown in Table 2. A multiple linear regression was calculated to predict $MK_l$ based on BFI measures. A significant equation was found, $F(4, 221) = 3.37$, $p < .01$, with an $R^2 = .07$. Only extraversion was shown to be a significant predictor of $MK_l$ above and beyond all other BFI measures ($\beta = 0.22$, $p < .01$).

Similar analyses for hyperactivity and inattention demonstrated a positive correlation of both measures with $MK_l$ ($r = .41, p < .01; r = .25, p < .01$). A multiple linear regression was calculated to predict $MK_l$ based on hyperactivity and inattention. A significant equation was found, $F(1, 221) = 23.99$, $p < .01$, with an $R^2 = .18$. Whereas hyperactivity predicted $MK_l$ positively ($\beta = 0.57, p < .01$), for inattention, a marginal suppression effect was found ($\beta = -0.20, p = .0052$). This means that inattention marginally predicted $MK_l$ negatively and in a lower magnitude compared with hyperactivity.

A multiple linear regression was calculated to predict $MK_l$ using hyperactivity and extraversion. A significant equation was found, $F(1, 221) = 23.18$, $p < .01$, with an $R^2 = .18$. It was found that hyperactivity predicted $MK_l$ above and beyond extraversion ($\beta = 0.39, p < .01$), but not vice versa ($\beta = 0.10$, $p = .12$). This suggests that extraversion and ADHD symptoms highly correlated, and that extraversion had no significant contribution to predicting $MK_l$ above and beyond hyperactivity. Consequently, hyperactivity was employed as the only intrinsic feature in further analysis.

### Impact of extrinsic features on delay discounting and the interaction with hyperactivity

The second and third hypotheses were that each of the extrinsic features (fungibility, perishability, and magnitude) has a main effect on the delay discounting rate, and that these effects are moderated by the level of intrinsic factors. Since we found that the dominant intrinsic measure is hyperactivity and since the existing literature consistently supports a dimensional structure of ADHD (Coghill & Sonuga-Barke, 2012), we added the hyperactivity score and the interaction between the hyperactivity score and the extrinsic factors to the model. A set of ANOVA tests (2 × 2), with either fungibility, perishability, or magnitude as within-subject independent variables,

**Table 2** Descriptive statistics of the study variables

| Questionnaire | Variable | Mean | *SD* | Min | Max | *r* |
|---|---|---|---|---|---|---|
| Big Five Inventory (BFI) | Extraversion | 3.00 | 0.64 | 1.50 | 4.50 | .15* |
| | Openness | 3.97 | 0.79 | 1.11 | 5.56 | −.07 |
| | Agreeableness | 3.68 | 0.75 | 1.44 | 5.00 | −.16* |
| | Conscientiousness | 4.30 | 0.88 | 1.13 | 5.63 | −.17* |
| | Neuroticism | 2.14 | 0.80 | 0.80 | 4.0 | .12 |
| Adult ADHD Self Report Scale (ASRS) | Hyperactivity | 12.99 | 8.20 | 0 | 35 | .41** |
| | Inattention | 14.05 | 7.95 | 0 | 35 | .25** |
| | ASRS total score | 27.04 | 15.33 | 0 | 66.0 | .35** |
| Online Delay Discounting Questionnaire (ODDQ) | $K_1$ – Sushi | 2.83 | 6.32 | <0.01 | 24 | .55** |
| | $K_2$ – Books | 1.21 | 4.81 | <0.01 | 24 | .70** |
| | $K_3$ - Restaurant voucher | 1.07 | 4.16 | <0.01 | 24 | .78** |
| | $K_4$ - Gift card for books | 1.15 | 4.52 | <0.01 | 24 | .81** |
| | $K_5$ – Cash | 0.95 | 4.07 | <0.01 | 24 | .78** |
| | $K_6$ – Chocolate | 2.12 | 6.13 | <0.01 | 24 | .64** |
| | $K_7$ – Shoes | 1.23 | 4.33 | <0.01 | 24 | .76** |
| | $K_8$ - Grocery voucher | 1.21 | 4.67 | <0.01 | 24 | .75** |
| | $K_9$ - Gift card for shoes | 1.63 | 5.36 | <0.01 | 24 | .79** |
| | $K_{10}$ – Cash | 0.89 | 3.96 | <0.01 | 24 | .78** |
| Quick Delay Questionnaire (QDQ) | Delay discounting | 11.51 | 4.04 | 5.0 | 23 | .38** |
| | Delay aversion | 13.32 | 4.24 | 5.0 | 25 | .17* |

*Note.* * $p < .05$, ** $p < .01$, *r* refers to the correlation between the variables and $MK_l$

hyperactivity as a between-subject independent variable, and $k_l$ as the dependent variable was used to test these hypotheses.

The first model examined the effect of magnitude by comparing the $K_l$ for \$100 versus \$500. The ANOVA revealed that magnitude had a small effect on the rate of delay discounting, $K_l\ (100) = -4.08 \pm 2.60, K_l\ (500) = -4.47 \pm 2.67$, $F(1, 220) = 4.13, p = .04, \eta_p^2 = .02$, suggesting that high-value rewards decline less steeply than low-value rewards. A main effect of hyperactivity was found on the delay discounting rate, $F(1, 220) = 40.48p < .01\eta_p^2 = .16$. No interaction between hyperactivity and magnitude was found $\left(F(1, 220) = 0.72, p = .40,\ \eta_p^2 < .01\right)$.

The second model examined the effect of perishability by comparing the mean $K_l$ for sushi and chocolate versus books and shoes. The ANOVA revealed that perishability had an effect on the rate of delay discounting, $K_l\ (\textit{sushi and chocolate}) = -2.41 \pm 2.52,\ \ K_l\ (\textit{books and shoes}) = -3.86 \pm 2.39$, $F(1, 220) = 38.34, p < .01, \eta_p^2 = .15$, implying that nonperishable rewards have a moderated delay discounting rate compared to perishable rewards. A main effect of hyperactivity was found, $F(1, 220) = 19.22, p < .01, \eta_p^2 = .08$. An interaction between hyperactivity and perishability did not reach significance $\left(F(1, 220) = 3.13, p = .08, \eta_p^2 = .01\right)$.

The third model examined the effect of fungibility by comparing the mean $K_l$ for books and shoes versus gift cards for books and shoes. The ANOVA revealed that fungibility had an effect on the rate of delay discounting, $K_l(\textit{books and shoes}) = -3.86 \pm 2.39,\ \ K_l(\textit{gift cards}) = -4.07 \pm 2.57$, $F(1, 220) = 6.05, p = .02, \eta_p^2 = .03$, indicating a lower discounting rate as the fungibility of the reward increases. A main effect of hyperactivity was found, $F(1, 220) = 37.42, p < .01, \eta_p^2 = .14$. An interaction between hyperactivity and perishability did not reach significance $\left(F(1, 220) = 3.58, p = .06, \eta_p^2 = .02\right)$.

The fourth model examined the effect of combined perishability and nonfungibility by comparing the mean $K_l$ for sushi and chocolate versus restaurant and grocery vouchers. The ANOVA revealed that the combined perishability and nonfungibility had an effect on the rate of delay discounting, $K_l\ (\textit{sushi and chocolate}) = -2.41 \pm 2.52,\ \ K_l\ (\textit{vouchers}) = -4.07 \pm 2.57, F(1, 220) = 64.21$, $p < .01, \eta_p^2 = .23$. A main effect of hyperactivity was found $F(1,\ 220) = 30.23, p < .01, \eta_p^2 = .12$. An interaction between hyperactivity and perishability was significant $\left(F(1, 220) = 10.36, p < .01, \eta_p^2 = .05\right)$. As Fig. 1 shows, the combined effect of nonfungibility and perishability was greater for people with low levels of hyperactivity symptoms compared with people with high levels of hyperactivity symptoms.

## Discussion

This study examines the effects of intrinsic and extrinsic features on delay discounting and the interaction between these features. Using a set of questionnaires, completed by 222 participants on the MTurk system, we administrated personality and ADHD measures, in addition to a set of choices between immediate and delayed hypothetical rewards, varying in levels of fungibility, perishability, and magnitude.

## Role of intrinsic features

The results replicated previous research in this field and showed that extraversion is the most important Big Five dimension to affect delay discounting rate (Hirsh et al., 2008). We also showed that both hyperactivity and inattention symptoms correlate with the delay discounting rate. Multivariate regression analyses found that only hyperactivity symptoms, underlies delay discounting rate, whereas inattention was marginally related to a lower delay discounting rate (Beauchaine, Ben-David, & Sela, 2017). This result is in agreement with a previous reports (Scheres et al., 2008; Scheres, Tontsch, Thoeny, & Kaczkurkin, 2010), suggesting that although hyperactivity and inattention comprise the same DSM-5 diagnosis of ADHD (American Psychiatric Association, 2013), only hyperactivity increases delay discounting, whereas inattention may have an opposite effect. From a methodological point of view, this finding suggests that if people who score high only on inattention and not hyperactivity are included in analyses of the link between ADHD on delay discounting, effects are suppressed.

An important finding presented here is that hyperactivity, rather than the Big Five personality traits, is the dominant factor in delay discounting tasks. Therefore, the focus of research and interventions on moderating delay discounting rate is suggested to be on ways that mitigate the hyperactivity symptoms. Some research has already been conducted on the impact of methylphenidate on delay discounting rate (Shiels et al., 2009). However, further research distinguishing between hyperactivity and inattention dimensions of ADHD could lead to more insights on the ways that people with hyperactive symptoms can reduce the occurrence of impulsive reactions.

## Role of extrinsic features

The results are also consistent with earlier work in this area, demonstrating a magnitude effect (e.g., Peters & Büchel, 2010) as well as significant effects of fungibility and perishability on decision-making (Holt et al., 2016). These results support the idea that decision-making and impulsive reactions can be moderated by modification of the rewards properties. Such results are relevant for behavioral approaches that use rewards to stimulate motivation and functioning. By providing a reward with specific properties, the associated behavior may be improved.

In the current study, fungibility and perishability showed greater effect sizes than magnitude. The small magnitude effect may be due to individuals' judgment that the values \$100 and \$500 (the two levels of magnitude used in this study) are on a similar scale of worth. Presumably, increasing the difference between the rewards would change the relations between the extrinsic features. Further research with additional reward values could be beneficial for understanding whether under some conditions the effect of magnitude may be more powerful.

This finding regarding the impact of reward type on decision-making is in line with previous research showing that monetary rewards declined more gradually than other consumable commodities (e.g., Estle et al., 2007).

## Interactions between intrinsic and extrinsic features

The experimental results revealed marginal interaction effects between hyperactivity and either perishability or fungibility, and a significant interaction effect for the combination of them (the steeper delay discounting rate for perishable and nonfungible reward compared with nonperishable and fungible rewards is less prominent in people with high levels of hyperactivity symptoms). This interaction might be considered to reflect a ceiling effect, assuming that the high-level hyperactivity group reached the maximum delay discounting

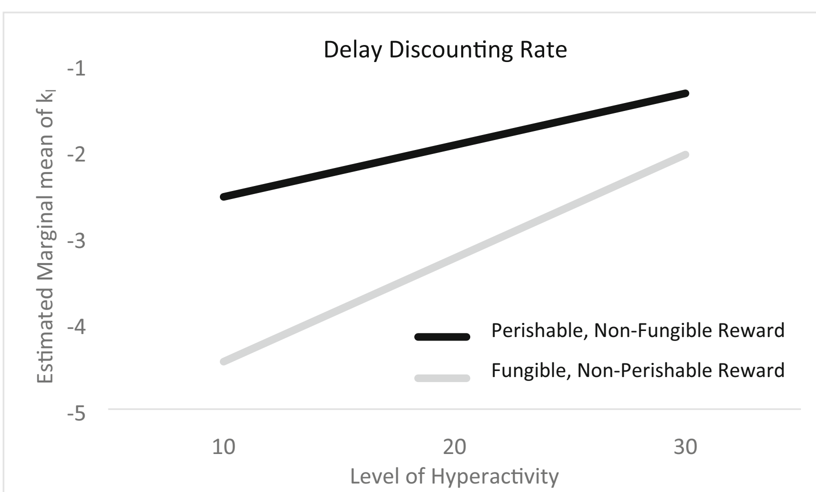


**Fig. 1** The delay discounting rate for perishable nonfungible versus the fungible nonperishable items

rate for the perishable and nonfungible rewards. That is, the impulsive response for perishable and nonfungible rewards cannot be higher, and therefore there is only a small gap in the delay discounting rate between fungible and nonfungible rewards. However, when examining the average indifferent point of the sushi $k_1$ (see Table 1 in Koffarnus & Bickel, 2014), we found that it is equivalent to a delay duration of approximately 7 hours (*SD*= ~4 hours). The highest possible delay discount rate is zero, and neither the sushi nor the chocolate reached this maximum rate. Thus, the results do not necessarily reflect a ceiling effect.

This interaction implies that adults with higher symptoms of hyperactivity are less sensitive to the fungibility and perishability of the reward compared with those with lower hyperactivity symptoms. The significance of this finding is in the understanding that the delay discounting rate is less moderated by increased perishability and nonfungibility of the reward among adults with higher symptoms of hyperactivity.

Taken together, these findings suggest that fungibility and nonperishability are strong features that can restrain impulsive responses, possibly due to the choice they provide regarding what and when to consume. However, these effects seem to be moderated by hyperactivity symptoms, suggesting that individuals with high symptoms of hyperactivity are mainly affected by their intrinsic feature, so the fungibility and nonperishability of the rewards, although recognized, only manage to control the impulsive response to a certain extent.

## Limitations and future directions

The experiments used sushi, chocolate, and other rewards to provide the participants a real experience, as much as possible. Yet the observed results may be somehow ambiguous, as the rewards differ in many ways beyond just fungibility and perishability. Better control on the differences between the rewards could achieve an improved analysis of the results.

In this study, we used a dimensional measure of hyperactivity, rather than a comparison between a clinical sample and a control group. The gap between the measures may indicate that with a higher number of clinical participants we could get other interactions or stronger evidence. Conducting an experiment with clinical participants may refine our findings and lead to a better understanding of the interaction between ADHD and extrinsic features.

## Concluding remarks

The current study is part of a growing body of literature on the factors that affect delay discounting. The contribution of this study is twofold. First, we replicated several previous studies on delay discounting, using a crowdsourcing service. Using an up-to-date experimental tool with only five questions to evaluate delay discounting, we managed to conduct several decision-making tasks in reasonable testing time and gathered a significant amount of data. The replications validate our experimental settings, which can be a platform for further research in this area.

Second, we introduced a primary set of interactions. These interactions clarify the conditions where a change in the reward properties could lead to a lower reaction and consequently might help to adapt behavioral treatment approaches. Accordingly, therapists that aim to reduce impulsivity reactions can benefit from these findings as well as economic models that deal with the decision-making of consumers.

## Appendix A

**Table 3** Correlation between the rewards

| | Sushi | Books | Restaurant Voucher | Gift Card for Books | \$100 Cash | Chocolate | Shoes | Grocery Voucher | Gift Card for Shoes | \$500 Cash |
|---|---|---|---|---|---|---|---|---|---|---|
| Sushi | 1 | .37** | .33** | .30** | .29** | .42** | .25** | .39** | .29** | .29** |
| Books | .37** | 1 | .50** | .51** | .50** | .38** | .48** | .45** | .48** | .46** |
| Restaurant Voucher | .33** | .50** | 1 | .62** | .60** | .34** | .56** | .57** | .53** | .67** |
| Gift Card for Books | .30** | .51** | .62** | 1 | .63** | .50** | .54** | .59** | .66** | .59** |
| \$100 Cash | .29** | .50** | .60** | .63** | 1 | .46** | .55** | .59** | .54** | .61** |
| Chocolate | .42** | .38** | .34** | .50** | .46** | 1 | .47** | .32** | .42** | .32** |
| Shoes | .25** | .48** | .56** | .54** | .55** | .47** | 1 | .46** | .65** | .61** |
| Grocery Voucher | .39** | .45** | .57** | .59** | .59** | .31** | .46** | 1 | .55** | .58** |
| Gift Card for Shoes | .29** | .48** | .53** | .66** | .54** | .42** | .65** | .55** | 1 | .65** |
| \$500 Cash | .29** | .46** | .67** | .59** | .61** | .32** | .61** | .58** | .65** | 1 |

Note ** $p < .01$

## References


American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th). Washington, DC: American Psychiatric Publications.

Beauchaine, T. P., Ben-David, I., & Sela, A. (2017). Attention-deficit/hyperactivity disorder, delay discounting, and risky financial behaviors: A preliminary analysis of self-report data. *PLOS ONE*, *12*(5), e0176933.

Bickel, W. K., Odum, A. L., & Madden, G. J. (1999). Impulsivity and cigarette smoking: Delay discounting in current, never, and ex-smokers. *Psychopharmacology*, *146*(4), 447–454.

Buhrmester, M., Kwang, T., & Gosling, S. D. (2011). Amazon's Mechanical Turk: A new source of inexpensive, yet high-quality, data? *Perspectives on psychological science*, *6*(1), 3–5.

Clare, S., Helps, S., & Sonuga-Barke, E. J. (2010). The quick delay questionnaire: A measure of delay aversion and discounting in adults. *ADHD Attention Deficit and Hyperactivity Disorders*, *2*(1), 43–48.

Coghill, D., & Sonuga-Barke, E. J. (2012). Annual research review: Categories versus dimensions in the classification and conceptualisation of child and adolescent mental disorders—Implications of recent empirical study. *The Journal of Child Psychology and Psychiatry*, *53*, 469–489.

Demurie, E., Roeyers, H., Baeyens, D., & Sonuga-Barke, E. (2012). Temporal discounting of monetary rewards in children and adolescents with ADHD and autism spectrum disorders. *Developmental Science*, *15*(6), 791–800.

Denissen, J. J., Geenen, R., Van Aken, M. A., Gosling, S. D., & Potter, J. (2008). Development and validation of a Dutch translation of the Big Five Inventory (BFI). *Journal of Personality Assessment*, *90*(2), 152–157.

Estle, S. J., Green, L., Myerson, J., & Holt, D. D. (2007). Discounting of monetary and directly consumable rewards. *Psychological Science*, *18*(1), 58–63.

Frederick, S., Loewenstein, G., & O'Donoghue, T. (2002). Time discounting and time preference: A critical review. *Journal of Economic Literature*, *40*(2), 351–401.

Goodman, J. K., Cryder, C. E., & Cheema, A. (2013). Data collection in a flat world: The strengths and weaknesses of Mechanical Turk samples. *Journal of Behavioral Decision Making*, *26*(3), 213–224.

Green, L., & Myerson, J. (2013). How many impulsivities? A discounting perspective. *Journal of the Experimental Analysis of Behavior*, *99*(1), 3–13.

Hirsh, J. B., Morisano, D., & Peterson, J. B. (2008). Delay discounting: Interactions between personality and cognitive ability. *Journal of Research in Personality*, *42*(6), 1646–1650.

Holt, D. D., Glodowski, K., Smits-Seemann, R. R., & Tiry, A. M. (2016). The domain effect in delay discounting: The roles of fungibility and perishability. *Behavioural Processes*, *131*, 47–52.

Huff, C., & Tingley, D. (2015). "Who are these people?" Evaluating the demographic characteristics and political preferences of MTurk survey respondents. *Research & Politics*, *2*(3), 2053168015604648.

Jackson, J. N., & MacKillop, J. (2016). Attention-deficit/hyperactivity disorder and monetary delay discounting: A meta-analysis of case-control studies. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging, 1*(4), 316–325. doi:https://doi.org/10.1016/j.bpsc.2016.01.007

John, O. P., Donahue, E. M., & Kentle, R. L. (1991). *The Big Five Inventory—Versions 4a and 54*. Berkeley: University of California, Berkeley Institute of Personality and Social Research.

Kessler, R. C., Adler, L., Ames, M., Demler, O., Faraone, S., Hiripi, E. V. A., .... Ustun, T. B. (2005). The World Health Organization Adult ADHD Self-Report Scale (ASRS): A short screening scale for use in the general population. *Psychological Medicine*, *35*(2), 245–256.

Koffarnus, M., Kaplan, B., & Stein, J. (2017). *User guide for Qualtrics® Minute Discounting Template*. Retrieved from https://scienceofbehaviorchange.org/wp-content/uploads/2017/08/Qualtrics-Minute-Discouting-User-Guide-1.1.pdf

Koffarnus, M. N., & Bickel, W. K. (2014). A 5-trial adjusting delay discounting task: Accurate discount rates in less than one minute. *Experimental and Clinical Psychopharmacology*, *22*(3), 222.

Madden, G. J., Begsotka, A. M., Raiff, B. R., & Kastern, L. L. (2003). Delay discounting of real and hypothetical rewards. *Experimental and Clinical Psychopharmacology*, *11*(2), 139.

Madden, G. J., & Bickel, W. K. (2010). *Impulsivity: The behavioral and neurological science of discounting*. Washington, DC: American Psychological Association.

Marx, I., Hacker, T., Yu, X., Cortese, S., & Sonuga-Barke, E. (2018). ADHD and the choice of small immediate over larger delayed rewards: A comparative meta-analysis of performance on simple choice-delay and temporal discounting paradigms. *Journal of Attention Disorders*, 1087054718772138.

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 analyses of behavior, Vol. 5. The effect of delay and of intervening events on reinforcement value (p. 55–73). Mahwah, NJ: Erlbaum.

McClure, S. M., Ericson, K. M., Laibson, D. I., Loewenstein, G., & Cohen, J. D. (2007). Time discounting for primary rewards. *The Journal of Neuroscience*, *27*(21), 5796–5804.

McClure, S. M., Laibson, D. I., Loewenstein, G., & Cohen, J. D. (2004). Separate neural systems value immediate and delayed monetary rewards. *Science*, *306*(5695), 503–507.

Odum, A. L. (2011a). Delay discounting: I'm a k, you're a k. *Journal of the Experimental Analysis of Behavior*, *96*(3), 427–439. doi:https://doi.org/10.1901/jeab.2011.96-423

Odum, A. L. (2011b). Delay discounting: Trait variable? *Behavioural Processes*, *87*(1), 1–9.

Pappas, D. (2006). ADHD Rating Scale-IV: Checklists, norms, and clinical interpretation. *Journal of Psychoeducational Assessment*, *24*(2), 172–178.

Patros, C. H., Alderson, R. M., Kasper, L. J., Tarle, S. J., Lea, S. E., & Hudec, K. L. (2016). Choice-impulsivity in children and adolescents with attention-deficit/hyperactivity disorder (ADHD): A meta-analytic review. *Clinical Psychology Review*, *43*, 162–174.

Peters, J., & Büchel, C. (2010). Episodic future thinking reduces reward delay discounting through an enhancement of prefrontal-mediotemporal interactions. *Neuron*, *66*(1), 138–148.

Petry, N. M., & Madden, G. J. (2010). Discounting and pathological gambling. In G. J. Madden & W. K. Bickel (Eds.), *Impulsivity: The behavioral and neurological science of discounting* (pp. 273–294). Washington, DC: American Psychological Association. doi: https://doi.org/10.1037/12069-010

Reuben, E., Sapienza, P., & Zingales, L. (2010). Time discounting for primary and monetary rewards. *Economics Letters*, *106*(2), 125–127.

Scheres, A., Dijkstra, M., Ainslie, E., Balkan, J., Reynolds, B., Sonuga-Barke, E., & Castellanos, F. X. (2006). Temporal and probabilistic discounting of rewards in children and adolescents: Effects of age and ADHD symptoms. *Neuropsychologia*, *44*(11), 2092–2103.

Scheres, A., Lee, A., & Sumiya, M. (2008). Temporal reward discounting and ADHD: task and symptom specific effects. *Journal of Neural Transmission*, *115*(2), 221–226.

Scheres, A., Tontsch, C., Thoeny, A. L., & Kaczkurkin, A. (2010). Temporal reward discounting in attention-deficit/hyperactivity disorder: The contribution of symptom domains, reward magnitude, and session length. *Biological psychiatry*, *67*(7), 641–648.

Sensation, P. (2013). Understanding consumer decisions using behavioral economics. *Decision Making: Neural and Behavioural Approaches*, *202*, 197.

Shiels, K., Hawk, L. W., Jr., Reynolds, B., Mazzullo, R. J., Rhodes, J. D., Pelham, W. E., Jr., … Gangloff, B. P. (2009). Effects of methylphenidate on discounting of delayed rewards in attention deficit/hyperactivity disorder. *Experimental and Clinical Psychopharmacology*, *17*(5), 291.

Tsukayama, E., & Duckworth, A. L. (2010). Domain-specific temporal discounting and temptation. *Judgment and Decision Making*, *5*(2), 72.

Ubfal, D. (2016). How general are time preferences? Eliciting good-specific discount rates. *Journal of Development Economics*, *118*, 150-170.

Yi, R., Gatchalian, K. M., & Bickel, W. K. (2006). Discounting of past outcomes. *Experimental and Clinical Psychopharmacology*, *14*(3), 311.

Yi, R., Mitchell, S. H., & Bickel, W. K. (2010). Delay discounting and substance abuse-dependence. In G. J. Madden & W. K. Bickel (Eds.), *Impulsivity: The behavioral and neurological science of discounting* (pp. 191–211). Washington, DC: American Psychological Association. doi:https://doi.org/10.1037/12069-007

Yoon, J. H., De La Garza, R., Newton, T. F., Suchting, R., Weaver, M. T., Brown, G. S., … Haliwa, I. (2017). A comparison of Mazur's k and area under the curve for describing steep discounters. *The Psychological Record*, *67*(3), 355–363.

Zohar, A. H., & Konfortes, H. (2010). Diagnosing ADHD in Israeli adults: The psychometric properties of the Adult ADHD Self Report Scale (ASRS) in Hebrew. *Israel Journal of Psychiatry and Related Sciences, 47,* 308–315.