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# Planning to make economic decisions in the future, but choosing impulsively now: are preference reversals related to symptoms of ADHD and depression?

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ADHD, depression, delay discounting, preference reversals, gains and losses

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**Abstract**

A preference for smaller immediate rewards over larger delayed rewards (delay discounting, DD) is common in attention deficit hyperactivity disorder (ADHD), but rarely investigated in depression. Whether this preference is due to sensitivity to reward immediacy or delay aversion remains unclear. To investigate this, we examined whether ADHD and depressive symptoms are associated with *preference reversals*: a switch from smaller immediate rewards to larger delayed rewards when smaller rewards are also delayed. We also examined whether these symptoms differentially affect DD of losses. In Study 1 undergraduates completed a questionnaire about ADHD symptoms, and performed a hypothetical DD task. In the NOW condition, participants were presented with choices between a small reward available today and a large reward available after one year. In the FUTURE condition both rewards were delayed with +1 year. In Study 2 undergraduates completed questionnaires about ADHD and depressive symptoms and performed a DD task with gains and losses. Participants showed preference reversals in both studies and tasks. Losses were less steeply discounted than gains. ADHD and depressive symptoms did not influence these effects. Depressive symptoms, but not ADHD symptoms, were associated with less economic choices in general. These findings suggest that impulsive choice in depression is not explained by sensitivity to reward immediacy. 

## Introduction

Attention deficit hyperactivity disorder (ADHD) is a common child and adolescent psychiatric disorder, characterized by age-inappropriate levels of inattention, impulsivity, and hyperactivity. One of the leading theories in ADHD research proposes that relatively strong preferences for small immediate rewards over larger delayed rewards are an important correlate of symptoms of ADHD (Sonuga-Barke, 2005; Sonuga-Barke *et al*., 2008).

 

Delay discounting (DD) tasks provide a sophisticated approach to examine these preferences. In DD tasks, individuals make repeated choices between a small, immediate reward (e.g. 10 euros today) and a larger, delayed reward (e.g. 100 euros in 30 days). DD refers to the decrease of the subjective value of the delayed reward as a function of increasing delay to the reward (Critchfield and Kollins, 2001; Monterosso and Ainslie, 1999).

DD designs have been widely applied in the field of adult impulsivity (see for an overview Scheres *et al.*, 2013), and ADHD. Most studies found that ADHD is associated with steep discounting of delayed rewards (Costa Dias *et al.*, 2013; Demurie *et al.*, 2012; Hurst *et al.*, 2011; Paloyelis *et al.*, 2010; Scheres *et al.*, 2010; Wilson *et al.*, 2011; but see also Chantiluke *et al.*, 2014; Scheres *et al.*, 2006), using a mix of real and hypothetical tasks. In real tasks, pre-reward delays are endured by participants, and rewards are actually paid. In hypothetical tasks, however, participants do not endure the delays, and do not receive the rewards. Increased discounting has also been found to be associated with increased self-reported ADHD symptoms in typical individuals (Anokhin *et al.*, 2011; Paloyelis *et al.*, 2009; Scheres *et al.*, 2008). It is still unclear, however, whether these "impulsive" choices are mainly due to increased sensitivity to *immediate* rewards, or to delay aversion (DA) (e.g. Sonuga-Barke, 2003; Sonuga-Barke *et al.*, 1992). It is important to know what it is that makes people choose impulsively, because it will help us understand how to intervene when an individual's impulsivity leads to harmful or unhealthy behavior.

Sensitivity to reward immediacy, i.e. the drive to obtain a reward right now, can occur due to weak inhibitory control or a steep delay of gratification gradient (Barkley *et al.*, 2001; Marco *et al.*, 2009). According to the DA model, however, impulsive choice (strong preference for small immediate reward) is driven by an acquired aversion to delay (Sonuga-Barke *et al.*, 1992), which is not necessarily related to reward. Marco *et al.* (2009) investigated the role of both factors by the use of a choice paradigm that included a post-reward delay condition. When participants chose the smaller sooner reward in this condition, they still needed to wait before the next trial started. The authors concluded that both a sensitivity to reward immediacy and DA contributed to the immediate reward preference of children with ADHD. In a DD study by Scheres *et al.* (2006) that included post-reward delays, it was also concluded that both factors contributed to choices for small immediate rewards in adolescents. In younger children (<10 years), however, reward immediacy was the main driving force.

In the current study we used another, complementary, approach, which did not involve post-reward delays, to investigate specifically the role of sensitivity to reward immediacy in DD. In the studies mentioned earlier, it can be difficult to fully disentangle sensitivity to reward immediacy from DA, as there is always an immediate reward option available. Therefore, both factors could lead to choices for immediate rewards, also in the post-reward delay condition. This study, however, focused on the use of a hypothetical DD task including a design allowing for the measurement of *preference reversals*: a switch in preference from smaller immediate rewards to larger delayed rewards when smaller rewards are also delayed in time (i.e. when a constant delay is added to both outcomes) (Green *et al.*, 1994). For example, someone might choose 10 euros over 100 euros in 30 days when the smaller sooner reward (e.g. 10 euros) is available *today*, but may choose to forego it and instead maximize their winnings, when the small reward is also delayed: choosing 100 euros after 37 days over 10 euros after seven days. This is a complementary way of studying the role of sensitivity to reward immediacy, and the use of a hypothetical task is appropriate for the age range under study here, as previous studies with hypothetical DD tasks have been shown to be sensitive to daily life impulsivity such as substance use in adult populations (e.g. Green and Myerson, 2004; Reynolds, 2006). Here, we examined whether ADHD symptoms in a student population influences preference reversals. If ADHD is associated with increased sensitivity to *reward immediacy*, individuals with more ADHD symptoms are expected to show especially steep discounting when the sooner reward is available today. If ADHD is associated with DA, they will choose the smaller *sooner* reward independent of whether it is available today or not.

Just like ADHD, major depressive disorder (MDD) is common in adolescence. MDD is characterized by depressed mood and/or anhedonia. Symptoms of both ADHD and MDD commonly emerge during childhood or adolescence, and often continue into adulthood. The symptoms of these disorders greatly overlap, such as low or irritated mood, loss of pleasure, sleep disturbances, and loss of concentration. Importantly, both disorders have been linked to altered reward processing (Chau *et al.*, 2004; de Zeeuw *et al.*, 2012; Forbes, 2009; Forbes and Dahl, 2005; Luman *et al.*, 2005; Luman *et al.*, 2010; Naranjo *et al.*, 2001; Sagvolden *et al.*, 1998; Sonuga-Barke, 2011). Abnormalities in the brain reward system have been associated with impulsivity (Johansen *et al.*, 2002; Sagvolden *et al.*, 1998; Tripp and Wickens, 2009). In line with these disturbances, both ADHD and depression are linked to disrupted dopamine signaling (Castellanos and Tannock, 2002; Johansen *et al*., 2002; Martin-Soelch, 2009; Naranjo *et al*., 2001; Tripp and Wickens, 2009), and both impulsive behavior and depression have been linked to serotonin disturbances (Carver *et al*., 2008; Jacobs and Fornal, 1995; Oades, 2007; Schreiber and De Vry, 1993).

While it has been well established that ADHD is associated with a relatively strong immediate reward preference, less is known about DD in depression. The handful of studies that have been conducted, have provided mixed results. A recent study by Pulcu *et al*. (2014) showed that patients with current MDD discounted delayed rewards more steeply than remitted patients and healthy controls when delayed rewards were large. This appeared to be associated with increased self-reported hopelessness. Steep discounting in depression was also found by Takahashi *et al*. (2008), when participants were given a choice between small immediate and larger delayed rewards. Lempert and Pizzagalli (2010), however, who employed a dimensional approach, found that students who scored high on anhedonia showed less steep discounting than others, and suggested that this was due to decreased responsiveness to immediate rewards.

An advantage of such a dimensional approach using a non-clinical sample is that effects of specific disorder-related symptoms can be examined more independently from other disorder-related symptoms than in a clinical sample in which symptoms often co-occur (cf. Lempert and Pizzagalli, 2010). Since many psychiatric disorders have overlap in symptomatology, as is the case with ADHD and depression, there is a need for studies that cut across disorders as they are traditionally defined and focus on specific domains of "disability" in line with the Research Domain Criteria (RDoC) developed by the National Institute of Mental Health (NIMH) (e.g. Sonuga-Barke *et al*., 2016; Whitton *et al*., 2015).

As both ADHD and depression are associated with altered reward sensitivity, reward-based decision-making (e.g. DD of rewards) is a relevant domain to examine in relation to the overlapping symptoms of these two disorders. It is also important to examine in what way the two disorders differ within this domain, to gain insight in possible unique symptom profiles that are associated with specific decision-making profiles. The two disorders, for example, appear to differ on punishment sensitivity. Depression is thought to be associated with a *hyper*sensitivity to punishment, reflected in maladaptive responses to negative feedback (e.g. Eshel and Roiser, 2010), while ADHD is thought to be associated with a *hypo*sensitivity to punishment (see Luman *et al*., 2005, for a review). Loss discounting may therefore differ between the two disorders. An example of real-world loss discounting is when someone buys a car, but instead of paying the complete sum immediately, decides to take on the car company's offer to pay later at the cost of increased interest. People typically tend to discount future losses less than future gains (Estle *et al*., 2006; Tanaka *et al*., 2014; Thaler, 1981), a phenomenon known as the *sign effect*. In other words, large delayed losses do not lose their value as quickly as large delayed gains do, resulting in less steep discounting of losses than gains, or as Thaler (1981) put it: "someone who appears very impatient to receive a gain may nevertheless take a 'let's get it over with' attitude towards losses". To our knowledge, there are no studies that have examined loss discounting in relation to ADHD yet, and only one study has examined loss discounting in depression. This study showed that depressed individuals preferred larger delayed losses over smaller immediate losses more often than controls (Takahashi *et al*., 2008), which could be interpreted as a hypersensitivity to immediate loss. When the immediate loss was also delayed, however, preference reversals occurred: depressed patients chose the smaller sooner loss more often than controls. Preference reversals in loss discounting have also been found in healthy volunteers (Holt *et al*., 2008).

In the present study we used a dimensional and trans-diagnostic approach by including a large group of undergraduate students with varying degrees of ADHD and depressive symptoms, and focused on the role of reward/loss immediacy in DD of hypothetical gains and losses. We describe the results of two studies. In Study 1 we examined preference reversals in DD of gains in relation to symptoms of ADHD. In Study 2 we aimed to (1) replicate the results of Study 1 using an independent sample of students, (2) examine the relationship between preference reversals in DD of gains and *depressive symptoms*, and (3) examine the relationship between preference reversals in DD of *losses* and symptoms of ADHD and depression.

We expected that ADHD and depressive symptoms would be associated with steeper discounting of gains, and larger preference reversals, i.e. especially steep discounting when a reward can be obtained immediately. Furthermore, steep discounting was expected to be related to symptoms of hyperactivity/impulsivity, and less to symptoms of inattention (Scheres *et al*., 2010). Preference reversals were expected to be stronger with increasing depressive symptoms, due to *decreased* discounting (more economic choices) when both rewards are delayed (cf. Takahashi *et al*., 2008). The same pattern of results was expected for losses and depressive symptoms, while for ADHD symptoms we can formulate three different hypotheses: (1) steeper discounting irrespective of loss immediacy, because individuals with more ADHD symptoms prefer to postpone having to deal with losses as much as possible *and* are less sensitive to large losses; (2) steeper loss discounting, but especially when immediate losses are involved, in line with a present bias, which will lead to larger preference reversals in individuals with more symptoms; (3) decreased loss discounting (more economic choices) irrespective of loss immediacy, because individuals with more ADHD symptoms prefer not to wait, in line with the DA hypothesis. Finally, we expected generally steeper discounting for gains than for losses in line with previous studies.

## Study 1: Delay discounting (DD) of gains in relation to ADHD symptoms

### Methods

#### Participants

Participants were recruited from a large pool of individuals (higher education students, mainly psychology and pedagogy students) who signed up to participate in research of Radboud University, Nijmegen, the Netherlands. A total of 468 individuals (mean [$M$] = 19.5 ± 3 years, 57 male) volunteered to participate in an online survey, for which they received course credit.

#### Procedure

The study was approved by the Ethics Committee of the Faculty of Social Sciences of Radboud University. Four questionnaires were administered online to participants, which took about 10 to 15 minutes. They filled out a questionnaire measuring DSM-IV symptoms of ADHD in adulthood, consisting of 23 items measuring symptoms of inattention, hyperactivity and impulsivity (Kooij and Buitelaar, 1997; Kooij *et al*., 2005). Participants were asked to rate the severity of these symptoms over the last six months on a four-point scale. This questionnaire has high internal and external validity in adults (Kooij *et al*., 2005; internal consistency in current study: inattention Cronbach's $\alpha = 0.82$, hyperactivity-impulsivity: $\alpha = 0.76$). In addition, participants filled out the Barratt Impulsiveness Scale (BIS-11; Patton *et al*., 1995) measuring trait impulsivity, and the Quick Delay Questionnaire (QDQ; Clare *et al*., 2010) measuring DD and DA. The BIS-11 consists of 30 items that measure three sub-factors of impulsivity: attentional, motor, and non-planning impulsivity. Although the BIS-11 is widely used, recent studies found no evidence to support a three-factor model (Coutlee *et al*., 2014; Reise *et al*., 2013; Steinberg *et al*., 2013). The total BIS-11 score was therefore used as a measure of the broad construct of impulsivity (internal consistency in current study: $\alpha = 0.73$). The QDQ is a 10 item-scale: five items measuring DD, and five items measuring DA. These two subscales have shown internal consistency and good test–retest reliability (Clare *et al*., 2010; in current study: DD $\alpha = 0.68$, DA $\alpha = 0.83$). Finally, participants answered 24 hypothetical DD questions.

#### Hypothetical delay discounting (DD) task (GAINS)

The DD task consisted of two conditions: a NOW condition in which participants had to choose between a smaller sooner reward available today and a larger reward available after one year, and a FUTURE condition, in which all choices were delayed with +1 year, i.e. the smaller sooner reward was available after one year and the larger later reward after two years. The larger later reward was fixed at 100 euros, whereas the smaller sooner reward was 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 95 euros. Two control questions, in which both the sooner and later reward were 100 euros, were added. These 24 questions were presented in a predetermined pseudo-random order, in which the position of the smaller sooner reward on the screen was counterbalanced (left/right). For written instructions, see Supplementary Material.

#### Data pre-processing and statistical analyses

Some items of the ADHD questionnaire measured the same symptom. For these paired items, we included the item with the highest score in the sum score. The sum of these items led to a score for hyperactivity/impulsivity and a score for inattention, both ranging from 0 to 27, based on nine items each (see also Niermann and Scheres, 2014).

For each individual, the subjective values (SVs) of the delayed rewards presented in the DD task were determined by two independent raters by using predetermined rules (see e.g. Critchfield and Kollins, 2001, and Supplementary Material). The SV corresponds to the amount of money at which an individual is indifferent between the larger delayed reward and the smaller sooner reward, and ranged between 2.5 and 100. Interrater reliability was high (both kappa values > 0.95). In cases of disagreement, SVs were corrected in accordance with the predetermined rules.

Repeated-measures analysis of covariances (ANCOVAs) were conducted using condition (NOW and FUTURE) as within-subjects variable, SV as the dependent variable, and symptom domain (hyperactivity/impulsivity or inattention) as covariates in two separate analyses.

### Data exclusion

Two male participants were excluded because they were outliers on the basis of their age: they were 55 and 67 years old. Fifteen participants (3.2%) were excluded from analyses, because they made two or more inconsistent choices in the DD task. The remaining 451 individuals (52 males) had a mean age of 19.3 ± 2 years.

## Results

### Descriptives

Scores of hyperactivity/impulsivity ($M = 8.4 \pm 3.9$, range: 0–25) and inattention ($M = 8 \pm 4.2$, range: 0–26) were normally distributed among the 451 individuals included in the analyses. There was a high correlation between the two symptom scores ($r = 0.52$, $p < 0.001$).

Of the 451 individuals, 24 (5.3%) scored within the clinical range of hyperactivity/impulsivity, and 25 (5.5%) within the clinical range of inattention problems (i.e. ≥ 6/9 symptoms).

### Main analyses

There was a main effect of condition on DD ($t(450) = 13.8$, $p < 0.001$, Cohen's $d = 0.50$), indicating that, as expected, participants more often chose the larger delayed reward in the FUTURE condition than in the NOW condition (see Figure 1).

This effect did not interact with symptoms of hyperactivity/impulsivity ($F(1,449) = 0.153$, $p = 0.70$, $\eta_p^2 < 0.001$), nor with symptoms of inattention ($F(1,449) = 0.568$, $p = 0.45$, $\eta_p^2 = 0.001$). There were also no significant main effects of either symptom domain on choice behavior (hyperactivity/impulsivity: $F(1,449) = 3.124$, $p = 0.078$, $\eta_p^2 = 0.007$; inattention $F(1,449) = 0.829$, $p = 0.36$, $\eta_p^2 = 0.002$).

### Exploratory analyses

Self-reported trait impulsivity (BIS-11), delay aversion (QDQ-DA), delay discounting (QDQ-DD), and ADHD symptoms were all moderately to highly correlated ($0.18 > r < 0.53$, all $p$ values $< 0.001$, see Table S1 in Supplementary Material). ANCOVA's showed that high scores on the three additional measures were associated with more choices for smaller sooner rewards, independent of

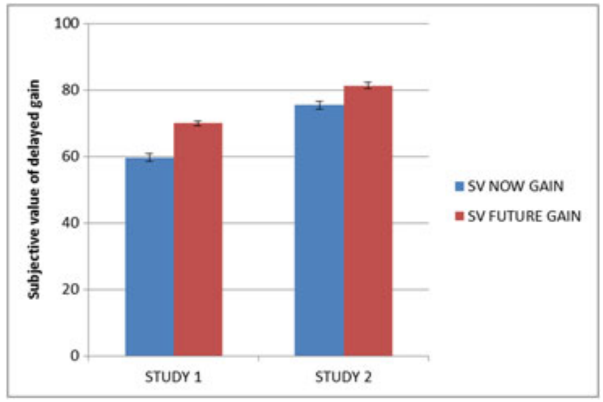


**Figure 1.** Subjective values (SVs) of delayed gain in the NOW and FUTURE condition of Study 1 and Study 2. See Supplementary Material for comparison between the two studies. Error bars represent standard error of the mean (SEM).

task condition (QDQ-DD: $F(1,449) = 27.925$, $p < 0.001$, $\eta_p^2 = 0.059$; QDQ-DA: $F(1,449) = 5.509$, $p = 0.019$, $\eta_p^2 = 0.012$; BIS-11: $F(1,449) = 5.431$, $p = 0.020$, $\eta_p^2 = 0.012$). Interactions between these measures and condition (NOW/FUTURE) did not reach significance.

## Study 2: Delay discounting (DD) of gains and losses in relation to ADHD and depressive symptoms

## Methods

### Participants

A new group of students ($N = 316$, $M = 19.6 \pm 3.3$ years, 44 male) volunteered to participate in an online survey.

### Procedure

The procedure was largely similar to Study 1. In addition to the questionnaires that were administered in Study 1, [1]we asked volunteers to fill out a questionnaire on depressive symptoms (Beck Depression Inventory, BDI, Beck *et al*., 1961; Bouman *et al*., 1985), on procrastination (Pure Procrastination Scale, PPS, Steel, 2010), and they answered 48 hypothetical DD questions to examine preference reversals of gains and losses.

[1] Internal consistencies of these questionnaires were similar to Study 1: inattention $\alpha = 0.85$, hyperactivity/impulsivity $\alpha = 0.74$ (ADHD questionnaire), trait impulsivity $\alpha = 0.73$ (BIS-11), DD $\alpha = 0.63$, and DA $\alpha = 0.85$ (QDQ).


Int. J. Methods Psychiatr. Res. 25(3): 178–189 (2016). DOI: 10.1002/mpr

The BDI consists of 21 items, each including four statements (0–3), assessing several symptoms of depression experienced in the last week (internal consistency in current study: $\alpha = 0.84$). A score of 10 to 18 is indicative of mild depressive symptoms, 19 to 29 indicative of moderate depressive symptoms, and $\geq 30$ is thought to reflect severe depressive symptoms (Bouman *et al.*, 1985). The PPS was added because procrastination is linked to impulsivity (Steel, 2010), and we aimed to explore its relationship with DD. Procrastination was expected to be associated with steeper loss discounting, especially in the NOW condition, i.e. a preference for larger delayed losses. The PPS consists of 12 statements (five-point scale). Together, these 12 items have been found to have a high reliability (Steel, 2010; internal consistency in current study: $\alpha = 0.89$).

### Hypothetical delay discounting (DD) task (GAINS and LOSSES)

Of the 48 questions, 24 were the same as in Study 1 (GAINS) and 24 were new, yet similar, questions to assess discounting of LOSSES. Again there was a NOW condition and a FUTURE condition. The LOSS task always followed the GAIN task. The instructions in the GAIN task were slightly different from Study 1. Participants now had to imagine that they received a one-time gift from the government, and that as time passes, they can receive more money because the amount accumulates on the government's bank account due to interest. In the LOSS condition participants had to imagine that they received a scholarship (loan) from the government which needs to be paid back at a certain point in time. As time passes, they pay more interest (see Supplementary Material for detailed written instructions).

### Data pre-processing and statistical analyses

We determined the SVs of the delayed gains and losses in both conditions (NOW/FUTURE) using the same predetermined rules as in Study 1. Interrater reliability was again high (kappa values $> 0.95$), and disagreements were corrected in accordance with our predetermined rules.

Repeated-measures ANCOVAs were conducted using condition (NOW/FUTURE), and task (GAIN/LOSS) as within-subjects variables, SV as the dependent variable, and symptom domain (hyperactivity/impulsivity, inattention or depression) as covariates in three separate analyses.

### Data exclusion

A 38-year old woman and a 61-year old man were excluded from analyses because of their age. A considerable number of participants ($N = 60$) answered the hypothetical loss discounting questions as if it concerned gains, making it impossible to determine a switch point (e.g. preferring to pay 95 euros now over 100 euros a year from now, while preferring to pay 100 euros a year from now over 5 euros today). This probably occurred because the loss task always followed the gain task, and participants might not have read the instructions carefully before continuing to the loss task. These answers were considered unreliable, and these participants were excluded from all analyses that included losses. No differences in hyperactive/impulsive, inattentive or depressive symptoms were found between the excluded and included individuals. An additional 28 individuals were excluded because they chose inconsistently on at least one of the four conditions, making it impossible to determine their switch point. The remaining 226 individuals (37 males) had a mean age of $19.5 \pm 2.2$ years.

## Results

### Descriptives

Inspection of histograms indicated that scores of hyperactivity/impulsivity ($M = 7.8 \pm 3.7$, range: 0–24) and inattention ($M = 7.8 \pm 4.5$, range: 0–26) were again normally distributed, and depression scores ($M = 6.8 \pm 6$, range: 0–39) were slightly skewed to the right. Hyperactivity/impulsivity and inattention again correlated highly as expected ($r = 0.59$, $p < 0.001$). Depressed symptoms also correlated positively with both measures of ADHD ($r = 0.31$, $p < 0.001$ for both measures).

Nine individuals (4%) scored within the clinical range of hyperactivity/impulsivity, 19 (8.4%) within the clinical range of inattention, and 12 (5.3%) within the range of moderate to severe depressive symptoms (≥19/63 on the BDI). Another 42 individuals (18.6%) scored within the range of mild depressive symptoms (10–18/63).

In the LOSS task, many participants chose the sooner loss on one of the control questions ($N = 129$). Not many participants chose the delayed reward on the control questions in the GAIN task, comparable to Study 1 (2.7% in both studies).

### Main analyses

We found a main effect of condition (NOW/FUTURE) ($F(1,224) = 99.63$, $p < 0.001$, $\eta_p^2 = 0.31$), indicating that preference reversals occurred across the gain and loss conditions. We also found a main effect of task (GAIN/LOSS) ($F(1,224) = 81.38$, $p < 0.001$, $\eta_p^2 = 0.27$); as expected, participants discounted gains more steeply than

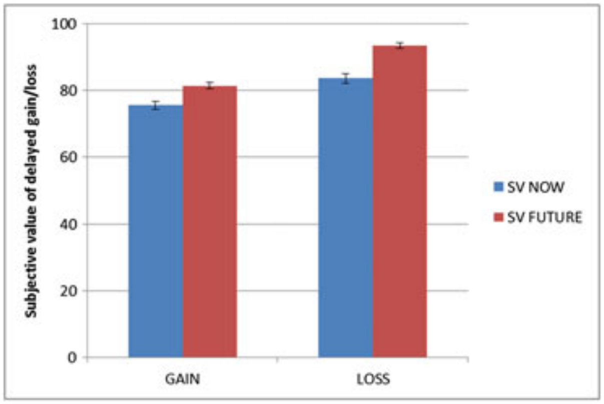


**Figure 2.** Subjective values (SVs) of delayed GAINS and LOSSES in the NOW and FUTURE condition in Study 2. Error bars represent standard error of the mean (SEM).

losses. In addition, an interaction between condition and task was found ($F(1{,}224) = 8.96$, $p < 0.01$, $\eta_p^2 = 0.038$); preference reversals were larger in the LOSS task than in the GAIN task (see Figure 2).

Again, hyperactivity/impulsivity and inattention were unrelated to discounting behavior: neither a main effect of hyperactivity/impulsivity was found ($F(1{,}224) = 0.088$, $p = 0.77$, $\eta_p^2 < 0.001$), nor of inattention ($F(1{,}224) = 0.05$, $p = 0.83$, $\eta_p^2 < 0.001$). There were also no interactions between ADHD symptoms and condition (NOW/FUTURE) or task (GAIN/LOSS).

Depressive symptoms, however, were associated with steeper discounting, independent of condition or task ($F(1{,}224) = 4.78$, $p = 0.03$, $\eta_p^2 = 0.021$; see Figure 3). This effect remained after controlling for hyperactivity/impulsivity, inattention, and trait impulsivity, but not after controlling for the DA and DD subscales of the QDQ. We subsequently examined whether the effect of depressive symptoms was driven by hopelessness about the future or by anhedonia, both measured by a single question of the BDI, but found no effects of these single items on discounting behavior (all $p$ values $> 0.12$, $\eta_p^2$ values $< 0.011$).

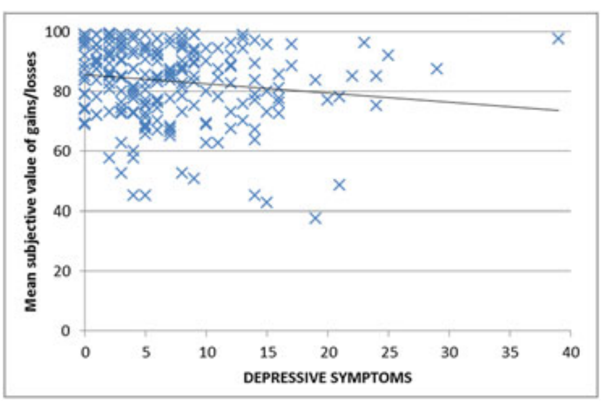


**Figure 3.** Subjective values of delayed gains and losses in Study 2 averaged across the two tasks (GAIN and LOSS) and the two conditions of each task (NOW and FUTURE) as a function of depressive symptoms.

### Analyses of self-reported trait impulsivity, delay aversion (DA) and delay discounting (DD)

High scores on the DA and DD subscales of the QDQ were again associated with steeper discounting, independent of task or condition (QDQ-DD: $F(1{,}224) = 10.15$, $p = 0.002$, $\eta_p^2 = 0.043$; QDQ-DA: $F(1{,}224) = 5.08$, $p = 0.025$, $\eta_p^2 = 0.022$). Importantly, when depressive symptoms were taken into account, the effect of DA no longer reached significance ($F(1{,}224) = 2.67$, $p = 0.104$, $\eta_p^2 = 0.012$). In addition, we found that the effect of the DD subscale was driven by a positive correlation with all task conditions except for future loss discounting, reflected in two significant two-way interactions (GAIN/LOSS × QDQ-DD: $F(1{,}224) = 8.74$, $p < 0.01$, $\eta_p^2 = 0.038$, NOW/FUTURE × QDQ-DD: $F(1{,}224) = 9.96$, $p < 0.01$, $\eta_p^2 = 0.043$).

This time, no significant effect of trait impulsivity (BIS-11) was found on discounting behavior, although the effect size was similar to that in Study 1 ($F(1{,}224) = 2.52$, $p = 0.11$, $\eta_p^2 = 0.011$). When gains were examined separately, however, and in a larger sample, because of less data drop-out due to misinterpretation of the loss task, we did find a significant main effect of trait impulsivity ($F(1{,}299) = 5.4$, $p = 0.017$, $\eta_p^2 = 0.019$).

### Exploratory analysis – procrastination (PPS)

We explored whether individuals who report to procrastinate more in daily life would show steeper discounting of both gains and losses than others, especially when immediate losses are involved. We found no effect of procrastination on discounting behavior (all $p$ values $> 0.19$, all $\eta_p^2$ values $< 0.009$). Procrastination did correlate highly with all other measures (see Table S2 in Supplementary Material)

## Discussion

This study provides evidence for preference reversals in DD of both gains and losses, and, importantly, shows that ADHD and depressive symptoms do not influence this effect. Depressive symptoms, however, appear to be associated with steeper discounting of gains and losses,


Int. J. Methods Psychiatr. Res. 25(3): 178–189 (2016). DOI: 10.1002/mpr

independent of whether these were immediate or in the future. Importantly, the effect of depressive symptoms was just as strong as the effect of DA. Steep discounting did not appear to be driven by hopelessness about the future or by anhedonia, but these symptoms were only measured with single items. These findings differ from the findings by Lempert and Pizzagalli (2010) who found that more anhedonic individuals made more economic, farsighted, choices. Our results are more in line with those by Pulcu *et al.* (2014) and Takahashi *et al.* (2008), who found increased discounting in depressed patients. As Pulcu *et al.* (2014) argued, pessimism about the future might be more influential in depression than current anhedonia, reflected in steeper discounting in general. Another factor that might play a role is altered time perception in depression. Individuals with depressive symptoms might perceive delays as longer than they actually are, which might explain why they prefer smaller sooner rewards, and why preference reversals are not necessarily increased in these individuals. It is also possible that depression is associated with a more realistic view of the future self (depressive realism, see also Pulcu *et al.*, 2014), leading to steeper discounting in both the NOW and FUTURE condition. It should be noted, however, that this latter finding does not correspond to what Takahashi *et al.* (2008) found. Their study showed that depressed patients were *more* impulsive than controls when an immediate reward/loss was available, but *less* impulsive when both rewards/losses were delayed (i.e. larger preference reversals). There are several differences between the study by Takahashi *et al.* (2008) and the present study that might explain this different finding. First of all, the participants in the study by Takahashi *et al.* (2008) had a clinical diagnosis, while our participants were mostly high functioning young adults. Second, not only patients with MDD, but also bipolar patients in a depressed state were included in the Takahashi *et al.* (2008) study. It is possible that depressive realism does not apply to these individuals, which may have led to more economic choices when both rewards/losses were delayed. Third, participants were older than those in the present study, and slightly more males than females were included, which could potentially influence discounting behavior. Finally, most participants in the study by Takahashi *et al.* (2008) used antidepressants. Although patients still scored high on depressive symptoms, it may have influenced decision-making.

Against expectations, no effects of ADHD symptoms were found on discounting behavior. Only when the data of the gain tasks in both samples were combined, a small, but statistically significant effect of hyperactivity/impulsivity was found in the expected direction, i.e. steeper discounting in individuals with higher levels of hyperactivity/impulsivity (see Supplementary Material). This latter finding is in line with a study in undergraduates by Scheres *et al.* (2008), in which an association between hyperactivity/impulsivity and DD was found, but only when delays and rewards were real. Perhaps a hypothetical task does not lead to such strong effects. As suggested by Scheres *et al.* (2008), individuals with higher levels of hyperactivity/impulsivity may *think* that they are more patient than they actually are when presented with real delays and real rewards. A possible lack of impairment in the current samples might also explain the lack of a strong association between hyperactive/impulsive symptoms and DD. Although the percentage of individuals that scored within the clinical range of ADHD symptoms (almost 10% across both samples) is in line with what would be expected on the basis of prevalence estimates in children (Polanczyk and Rohde, 2007), the participants in this study were all highly educated, suggesting that they are high functioning individuals. Importantly, the two present samples together with the study by Scheres *et al.* (2008) suggest that impulsive, or less economic, choices in late adolescents are not due to attention problems, in contrast to a previous population study in children (7–11 years) by Paloyelis *et al.* (2009).

In addition to providing evidence for preference reversals, Study 2 also provided evidence for the sign effect: losses were less steeply discounted than gains, in line with previous studies (e.g. Estle *et al.*, 2006). This indicates that people are in general more loss averse than reward prone. This study also replicated the occurrence of preference reversals in loss discounting (Holt *et al.*, 2008). An interesting new finding is that preference reversals were stronger in the loss task than in the gain task, suggesting that participants were especially averse to *immediate* loss whereas in the future they chose more economically. This effect might have been largely driven by a ceiling effect in the FUTURE condition. People appear to be less likely to take financial risks for their future selves, when there is no immediate loss option involved. In the current study the sooner option was either immediate or delayed by one year. It would be useful, however, to know at what delay people start to choose economically. Holt *et al.* (2008) has shown that the proportion of people that choose the smaller sooner payment increases as the delay to the sooner payment increases, but that the delay-difference between the sooner and later payment plays a role as well. More specifically, with increasing delay-difference, an increasingly larger delay to the sooner payment is needed before someone prefers the sooner payment above the larger later payment. It is also important to recognize individual differences in choice behavior. More than half of the participants in Study 2 (57%) preferred a sooner 100 euro loss above a later 100 euro loss. Apart from a few individuals who may have unintentionally chosen this option, it clearly indicates a "let's get it over with" attitude. The other half, however, did show loss discounting.

One of the main purposes of Study 2 was to examine (preference reversals in) DD in relation to the overlap and uniqueness of ADHD and depressive symptoms. We expected overlap in reward-based decision-making, but this was not the case: only depressive symptoms were associated with impulsive choices in the gain condition. This points in the direction that the reward system in depression is altered; increased levels of depression appear to be associated with a hyposensitivity to rewards in general, rather than a hypersensitivity to reward immediacy, given the fact that we found no association between depressive symptoms and preference reversals. In ADHD, however, this might be less straightforward, because there might be a competition between DA and hypersensitivity to (larger) rewards. Further, we expected divergence in loss-based decision-making, and although this was the case, findings were not in line with our expectations. We had expected that individuals with more ADHD symptoms would show steeper loss discounting independent of whether there was an immediate loss involved or not, but instead, this result was found for individuals with depressive symptoms. This suggests that, contrary to expectations, depressive symptoms were associated with a hyposensitivity to larger future losses. Together, these results point in the direction of a blunted response to both reward and punishment in depression, whereas in ADHD, different, perhaps opposing, factors (DA, hypersensitivity to rewards) might contribute to choice behavior that could cancel each other out. It should be noted that this might be different in a clinical ADHD population, in which DA might outweigh a hypersensitivity to reward, or vice versa. Future studies should address in more detail what it is that makes individuals with depressed symptoms, but not those with ADHD symptoms, more impulsive in a DD task, as our results show that attention problems and DA are not the main factors influencing this behavior. Questionnaires that tap into reward sensitivity and anhedonia in more detail, on the one hand, and hopelessness about the future (including suicidal ideation), on the other hand, might give more insight, but also perception of time and depressive realism deserve more attention. Likewise, future studies should try to disentangle the possibly competing roles of DA and reward/punishment sensitivity in reward- and loss-based decision-making in individuals with ADHD symptoms. Furthermore, neuroimaging studies could increase our understanding of the overlap and differences in the underlying neural substrates of reward- and loss-based decision-making between the two disorders.

Several limitations of this study should be mentioned. First, we do not know whether participants were diagnosed with a psychiatric disorder or whether they took medication. Although diagnostic status is less important in a dimensional approach, it is possible that individuals with symptoms of ADHD or depression do not experience impairment in daily life. More importantly, the use of medication may have influenced the severity of symptoms that were reported. Second, we had an unequal gender distribution (86% female), which may have influenced our results, as depression is twice as common in females as in males, while the opposite is true for ADHD. The lack of a strong association between ADHD symptoms and DD could perhaps be due to a lack of males in our sample. Third, in Study 2 we had to exclude participants because they appeared to have misinterpreted the loss discounting questions. One disadvantage of the use of online questionnaires is that there is no controlled environment, and that we cannot be sure whether respondents read and understood instructions. We should, however, note that two major advantages of administering questionnaires online is that it is a very small burden for volunteers, leading to large sample sizes and high statistical power, and that the absence of an experiment leader could diminish socially desirable answers. Finally, we do not know whether the findings in relation to ADHD and depressive symptoms are limited to the use of our hypothetical DD task, or whether the same results would have emerged if we had used an experiential DD task, or tasks that tap into other forms of impulsivity, such as waiting impulsivity, or reflection impulsivity (see e.g. Voon, 2014).

To conclude, we found no evidence for *increased* sensitivity to immediate rewards or losses (reward/loss immediacy), as measured with preference reversals, in late adolescents with higher levels of ADHD or depressive symptoms. Depressive symptoms and DA, however, appear to contribute to impulsive choice in a DD task. Future studies should examine depressive symptoms in more detail in order to pinpoint what is causing steep discounting in depression.

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## Declaration of interest statement

The authors have no competing interests.

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