Changing choices: a neurocognitive examination of decision-making during adolescence

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CHAPTER 2

Developmental changes and individual differences in temporal discounting during adolescence

Nikki C. Lee [1,2,] Renate H.M. de Groot [1,2,3,] Annemarie Boschloo[1], Sanne Dekker[1], Lydia Krabbendam[1] & Jelle Jolles[1]

1. Department of Educational Neuroscience, Faculty of Psychology and Education, VU University Amsterdam, Amsterdam, The Netherlands
2. Division of Cognitive Neuropsychiatry and Clinical Neuroscience, School for Mental Health and Neuroscience, Maastricht University, Maastricht, The Netherlands
3. Centre for Learning Sciences and Technologies, Open University, Heerlen, The Netherlands

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ABSTRACT

This study examined age-related changes in a specific aspect of adolescent decision-making, namely the preference for future versus immediate outcomes. A sample of 622 Dutch adolescents aged 12 -17 years completed a temporal discounting task. Participants were asked to choose between a delayed reward of €50 or an immediate reward of lower value. The delay interval was varied in three blocks (1 week, 1 month, 6 months). Results showed that preferences for large delayed rewards over smaller immediate rewards increased with age: late adolescents made more long-term decisions than early adolescents. A higher level of education was associated with an increased preference for long-term rewards, though the difference between the two groups decreased with age. These results suggest that late adolescents are less susceptible to the competing presence of an immediate reward when making long-term decisions, a skill which becomes increasingly important as they transition into adulthood.

INTRODUCTION

Adolescents are often characterised as impulsive and unable to plan ahead or envisage the long-term effects of their behaviour. Statistics show that they are more likely than adults to be involved in activities with potentially dangerous consequences such as road traffic accidents, smoking, drug use or unsafe sexual behaviours (Reyna & Farley, 2006; Steinberg, 2008). It has been suggested that this is due to the increased

salience during adolescence of the immediate rewards resulting from engaging in risky behaviour (Casey, Getz, & Galvan, 2008). Combined with the relative immaturity of self-control processes (Luna, Garver, Urban, Lazar, & Sweeney, 2004), due to continued structural and functional development of the adolescent brain (Giedd, 2004; Gogtay, et al., 2004), this results in a vulnerability towards decision-making behaviour that is motivated by a desire for immediate gratification. However, adolescence is a period during which many decisions are made that require weighing up both short and long-term costs and benefits, such as deciding between getting a job or going to university, or spending a weekend studying for an important exam or going out with friends. Therefore, it is important to understand how the ability to choose between immediate and delayed rewards develops during adolescence, as these skills may be vital to ensure a successful transition to adulthood.

Recently, the ability to delay gratification has been examined in adolescent samples using a behavioural paradigm known as temporal discounting (Christakou, Brammer, & Rubia, 2011; Olson, et al., 2009; Olson, Hooper, Collins, & Luciana, 2007; Steinberg, et al., 2009). Temporal discounting tasks measure the decline in the subjective value of a future reward as the time between the decision and the delivery of the reward increases (Ainslie, 1975; Green, Fry, & Myerson, 1994; Rachlin, Raineri, & Cross, 1991). Adolescents with a steeper rate of temporal discounting are more driven by immediate gratification than by the long-term consequences of their behaviour. The value of the delayed reward therefore decreases strongly as the delay interval increases. This comparison of immediate and delayed rewards makes temporal discounting tasks useful in examining the tradeoffs made by adolescents when making reward-related decisions. Within a temporal discounting task, a participant completes multiple trials with consistent delayed rewards but varying delay intervals (e.g. 'Would you prefer €10 today or €15 tomorrow, next week, next month, next year?'). The data resulting from these repeated trials gives an estimation of the rate at which the subjective value of the delayed reward decreases in value over time, i.e. is discounted. This is known as the discount rate (Myerson & Green, 1995). The subjective value of the delayed reward at each time point is known as the indifference point, and is equal to the amount at which the participant finds the larger future

and smaller current reward of equal value (Myerson, Green, & Warusawitharana, 2001). In adolescents, higher rates of discounting have been found in specific groups, such as smokers compared to non-smokers (Reynolds & Fields, 2012), as well being a characteristic of certain developmental disorders such as attention deficit hyperactivity disorder (Barkley, 1997).

A few studies have examined developmental changes in discounting behaviour during adolescence. Initial studies often compared a single group of adolescents of diverse ages to groups of young or older adults. For example Green, Myerson and Ostaszewski (1999) collected data from a group of young adolescents and found them to discount the value of delayed rewards more steeply then a group of college students and a group of older adults. A subsequent study by Scheres and colleagues (2006) examined changes during the adolescent period in more detail. They compared groups of primary and secondary school children and found that the younger group discounted significantly more strongly than the older group. Other studies using a similar age range have demonstrated comparable results (e.g. Olson, et al., 2007). However, the broad age ranges used in these studies did not allow for systematic examination of changes within the adolescent age range. A recent study by Steinberg et al. (2009) examined these changes in more detail. They found that young adolescents, aged 13 and younger, discounted significantly more steeply than adolescents aged 16 and older, with 14 and 15 year olds falling somewhere in between. No significant age differences were found in the older age groups, which ranged from 17 to 30 years of age.

Individual differences that may influence discounting behaviour, such as sex and level of education, have previously been examined in adult samples. Higher income and higher levels of education have been associated with lower discount rates (De Wit, Flory, Acheson, McCloskey, & Manuck, 2007; Harrison, Lau, & Williams, 2002; Jaroni, Wright, Lerman, & Epstein, 2004). Discount rates have been shown to have a negative association with grade point average in university students (Kirby, Winston, & Santiesteban, 2005; Silva & Gross, 2004). Previous studies of sex differences have reporting varying findings. Most studies reported higher discount rates in females compared to males (Reimers, Maylor, Stewart, & Chater, 2009; Reynolds, Ortengren,

Richards, & de Wit, 2006), though one study found men to discount more steeply than women (Kirby & Marakovic, 1996) and two studies found no differences between the sexes (Harrison, et al., 2002; Steinberg, et al., 2009). In adolescents, the effects of level of education and sex have not been studied extensively.

When taken together, the results of the aforementioned studies suggest that discounting behaviour continues to develop during adolescence and may be influenced by individual differences. However, these studies have analysed differences in discounting behaviour by comparing only one general discounting metric such as the discount rate. Such metrics summarise intertemporal preferences measured across several delay intervals into one quantitative variable, thereby disregarding differences in discounting behaviour in relation to these specific delay intervals. However, a recent study in adults and adolescents showed that differences between them in discounting behaviour became more apparent as delay intervals were increased (Christakou, et al., 2011). This suggests that examination of indifference points, which reflect intertemporal preferences at specific delay intervals, will lead to a better understanding of exactly how adolescent development affects decision-making at varying intervals between the decision and its consequences. For example, adolescent A may have a higher discount rate than adolescent B, suggesting that he is always more drawn to immediate rewards. However, this higher discount rate could be the result of a higher preference for immediate rewards for long delay intervals (e.g. six months) not short delay intervals (e.g. a week). In fact, adolescent A's indifference points for short delay intervals could be identical to those of adolescent B, with only his indifference points for long delay intervals causing the differences between them in discount rate. However, this can only be established through examination of indifference points and not through comparison of discount rates. By examining indifference points in this study, we hope to draw conclusions about in which delay intervals the temporal aspects of the decision are most influential during adolescence.

The aims of the current study are threefold. First, we aim to further examine the previously mentioned findings of Steinberg et al. (2009). We will use a narrow age range (12-17 years) so that close evaluation of developmental trajectories is possible. Secondly, we aim to extend previous findings by examining if behaviour differs when

the time between the immediate and delayed reward is a week, month or six months. Age-related changes in these specific indifference points have not been examined in previous studies, but will elucidate the causes of developmental changes in the previously examined discount rates. And finally, we will analyse the role of individual differences between adolescents, namely sex and level of education, on discounting behaviour.

To this end, a large cross-sectional sample (N = 622) of Dutch secondary school pupils, enrolled in the two highest levels of education, completed a temporal discounting task. We hypothesise that discount rates will decrease with age, i.e. that participants will become less oriented towards immediate rewards. We expect that this change will differ between indifference points. More specifically, we expect changes in discounting behaviour to be positively associated with delay intervals: the longer the interval the larger the decrease in discounting with age. Furthermore, we anticipate that individual differences, such as level of education and sex, will influence this development. In line with previous research we expect that boys and girls will differ in their discounting behaviour and that pupils enrolled in a lower level of education will report steeper discounting than those in a higher level of education.

METHOD

PARTICIPANTS

The initial sample included 691 adolescents between the ages of 12-17 years, recruited within a larger research project examining adolescent cognitive development. To be included in the sample for the present study, participants had to be typically developing with no prior history of neurological, psychological and/or psychiatric conditions, such as ADHD or an autism spectrum disorder. Application of these criteria led to exclusion of 37 participants, yielding a sample of 654 participants for the current analyses. Participants were divided into three age groups: early adolescents aged 12-13, mid-adolescents aged 14-15 and late adolescents aged 16-17. Participant characteristics following exclusion are presented in Table 1. All participants were enrolled in either senior general secondary education (hoger algemeen vormend onderwijs or 'havo') or pre-university education (voorbereidend wetenschappelijk

onderwijs or 'vwo'). These constitute the two highest levels of education within the Dutch system and approximately 40% of pupils are enrolled in one of these tracks. Students are placed in these tracks based on their performance on national standardised tests at the end of primary school. Graduation with either a havo or vwo diploma enables the student to enter higher education at respectively college or university level.

The VU University Amsterdam institutional ethical review board approved all procedures. Written informed consent was obtained from both participants and their parents prior to participation in the study.

Table 1 - *Participant characteristics (following exclusion)*

	AGE	MALE: FEMALE RATIO	LEVEL OF EDUCATION		*N*
	M (SD)		SENIOR GENERAL EDUCATION *(N)*	PRE-UNIVERSITY EDUCATION *(N)*	
AGE 12-13	12.62 (.49)	104:117	105	116	221
AGE 14-15	14.36 (.48)	104:148	123	129	252
AGE 16-17	16.48 (.50)	71:121	82	110	192
TOTAL	14.39 (1.60)	279:386	310	355	665

PROCEDURE

Researchers visited selected schools and gave a short presentation to the pupils about the research project. All pupils received an information package to take home, containing information about the project, a consent form and a questionnaire to be filled in by one of the child's parents or caretakers. Pupils returned the questionnaire and consent form a week later if they wished to participate. During this second session, pupils completed questionnaires and tasks in class under supervision of two trained psychologists and a classroom teacher. Completion of tasks and questionnaires took approximately 40 minutes, of which 5 minutes were spent on the temporal discounting task. All pupils who returned the information package were included in the testing procedure. Their non-participating classmates worked silently on a task provided by their classroom teacher. 38% of pupils elected to participate. Participants who did not

meet the inclusion criteria were removed from the analyses at a later date.

MEASURES

DEMOGRAPHICS

By means of a questionnaire filled in by the child's parents or caretakers, information was gathered about the child's medical history and educational background. This was used to identify participants who did not meet the inclusion criteria.

TEMPORAL DISCOUNTING

A written version of a temporal discounting task, based on the procedure used by Rachlin et al., (1991), was used to measure temporal discounting behaviour. The current task required participants to choose between a fixed delayed reward of €50 and a variable immediate reward of €5, €10, €15, €20, €25, €30, €35, €40 or €45. These amounts were chosen as they were deemed close to amounts the adolescents could realistically receive, as previous research has shown that the rate of temporal discounting is influenced by reward magnitude (Green, Myerson, & McFadden, 1997). Choices were presented as separate items and in ascending order. All rewards were hypothetical, as comparisons of tasks using real and hypothetical rewards have shown no difference in the results found (Johnson & Bickel, 2002; Madden, Begotka, Raiff, & Kastern, 2003; Madden, et al., 2004). Three interval lengths for the time between the immediate and delayed rewards were used: 1 week, 1 month and 6 months. The responses were used to determine each participant's indifference point for the three delay periods, defined as the item where participants switched from selecting the delayed reward to selecting the immediate reward. Lower indifference points indicate less willingness to wait for the delayed reward.

ANALYSES

All analyses were performed using PASW Statistics 17.0 for Mac. The area under the curve (AUC) method was used to calculate a measure of overall discounting behaviour and enable comparison with previous studies. This approach is frequently used within experimental research paradigms (e.g. Dixon, Marley, & Jacobs, 2003;

Olson, et al., 2007; Scheres, et al., 2006) as it avoids the difficulties associated with methods based on theoretical discounting functions (Myerson, et al., 2001). To this end, participants' indifference points were normalised, i.e. the delay was recalculated as a proportion of the maximum delay of 6 months and the value of the indifference point was recalculated as a proportion of the maximum reward of €50. Using these normalised values the three indifference points were plotted against (time to) delay. Vertical lines were drawn from each data point to the x-axis, thereby creating three trapezoids. The area under the resulting curve was calculated by summing the areas of these three trapezoids (see Myerson et al., (2001) for more information on the procedure). Due to normalization of the data points the AUC values range between 0.0 and 1.0, with smaller values indicating steeper discounting (i.e. less willingness to wait as time increases).

All effects are reported as significant at $p < .05$. To enable comparison of our data with previous research and to measure general discounting behaviour, our first analysis comprised a three-way analysis of variance (ANOVA) using age, sex and level of education as independent variables and the total area under the discounting curve as a dependent variable. Subsequently, in our second analysis, changes in discounting behaviour over time were examined using a repeated measures ANOVA, with individuals' three indifference points (week, month, 6 months) as the within-subjects factor and age, sex and level of education as between-subjects factors. Mauchley's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 86.186$, $p < .001$. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .886$). To further examine the effects of the individual difference variables at each delay interval, three separate three-way analyses of variance were performed using each of the three individual indifference points as dependent variables and age, sex and level of education as independent variables. In all analyses, significant main effects were further examined using post hoc Bonferroni-adjusted pairwise comparisons where appropriate. Significant interaction effects were investigated using post hoc simple effects analyses.

RESULTS

Participants who produced inconsistent discounting data (N = 32) were excluded from further analysis, in line with methods used in previous studies (Olson, et al., 2007; Reynolds, et al., 2006). Inconsistent discounting was defined as an increase in subjective value as time increased. Analysis showed that consistent and inconsistent discounters did not differ with regard to age, sex or level of education.

ANALYSIS 1: AREA UNDER THE CURVE

A three-way analysis of variance showed a significant main effect of age on the area under the discounting curve (F (2, 622) = 7.667, p = .001, partial η^2 = .02), with post hoc tests indicating that participants in the youngest age group (aged 12-13 years) discounted rewards more strongly than those in the oldest age group (aged 16-17 years). A significant main effect of level of education was also found (F (2, 622) = 31.53, p < .001, partial η^2 = .05), due to stronger discounting by participants in the lower level of education (havo), compared to the higher levels of education (vwo). There was no significant difference in discounting behaviour between boys and girls (F (1, 622) = .03, p =. 86, partial η^2 = .00).

ANALYSIS 2: INDIVIDUAL INDIFFERENCE POINTS

As is to be expected when using a temporal discounting task, the subsequent repeated measures ANOVA showed a significant main effect of repeated time factor (Greenhouse-Geisser F (1.77, 1098.32) = 824.81, p < .001, partial η^2 = .67) with participants discounting more strongly as the delay interval increased. A significant interaction was found between the repeated time factor and level of education (Greenhouse-Geisser F (1.77, 1098.32) = 7.14, p = .001, partial η^2 = .02), showing that pupils in the two levels differed in their changes in discounting behaviour over the three delay intervals (see Table 2). The interaction between the repeated time factor, age and level of education showed a trend towards significance (Greenhouse-Geisser F (1.77, 1098.32) = 2.202, p = .075, partial η^2 = .01). Tests of between-subject effects showed a significant main effect of age (F (2, 622) = 8.244, p < .001, partial η^2 = .03) and level of education (F (1, 622) = 31.829, p < .001, partial η^2 = .05), indicating

Table 2 - *AUC and indifference points as a function of age and level of education*

	TOTAL SAMPLE	12-13 YRS		14-15 YRS		16-17 YRS	
		SENIOR GENERAL EDUCATION	PRE-UNIVERSITY EDUCATION	SENIOR GENERAL EDUCATION	PRE-UNIVERSITY EDUCATION	SENIOR GENERAL EDUCATION	PRE-UNIVERSITY EDUCATION
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
AUC	.59 (.25)	.45 (.26)	.62 (.27)	.56 (.25)	.62 (.23)	.58 (.25)	.69 (.25)
INDIFFERENCE POINT WEEK	€43.15 (8.42)	€39.05 (12.49)	€44.32 (5.85)	€42.95 (8.42)	€43.86 (7.87)	€43.86 (7.41)	€44.66 (5.78)
INDIFFERENCE POINT MONTH	€34.37 (14.16)	€26.53 (16.46)	€36.32 (13.28)	€33.41 (14.32)	€36.54 (12.26)	€34.53 (14.03)	€38.13 (11.90)
INDIFFERENCE POINT SIX MONTHS	€20.34 (16.76)	€14.22 (14.57)	€21.48 (16.79)	€17.97 (16.21)	€21.52 (16.14)	€18.61 (16.98)	€27.48 (17.27)

that on average age groups and school types differed in their discounting behaviour across time points.

With respect to the individual indifference points, follow-up three-way analyses of variance for each indifference point showed a significant main effect of age (F (2, 622) = 5.578, p = .004, partial η^2 = .02) and level of education (F (1, 622) = 24.118,

Figure 1 - *Age differences in temporal discounting among senior general education (havo) pupils*

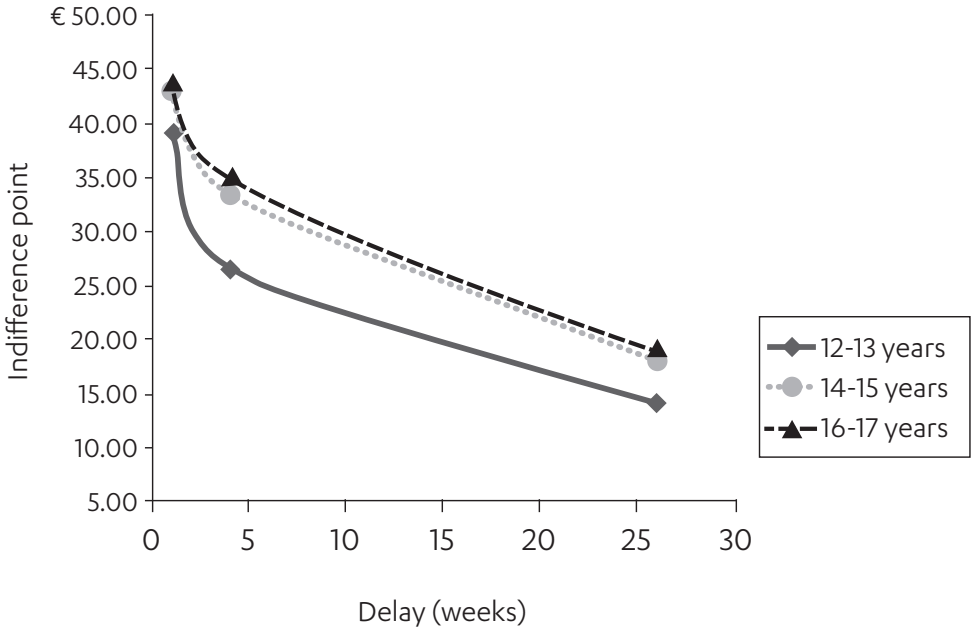
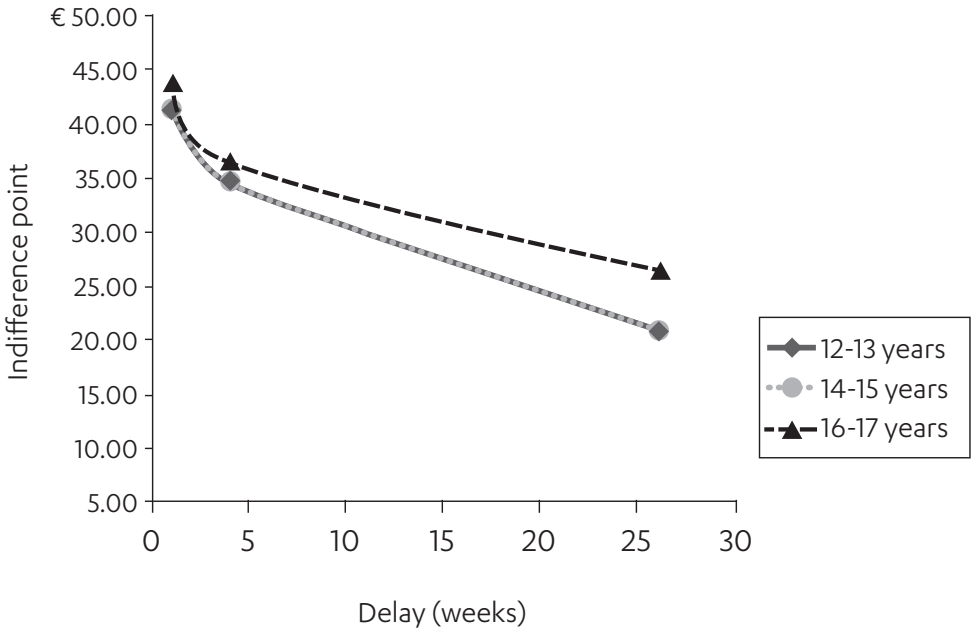


Figure 2 - *Age differences in temporal discounting among pre-university education (vwo) pupils*



$p < .001$, partial $\eta^2 = .04$) for the six month delay interval, with indifference points increasing with increased age and level of education. In contrast, a significant interaction was found for age group and level of education for the week (F (2, 622) = 4.609, $p = .01$, partial $\eta^2 = .02$) and month (F (2, 622) = 3.609, $p = .028$, partial $\eta^2 = .01$) delay intervals. This signified that for these shorter delay intervals the age effect was influenced by level of education. To further examine this effect, post hoc simple effects analyses were used. As Figures 1 and 2 show, the pattern of age differences was not the same across the two levels of education. For both the week and month delay intervals significant age effects were only present for the lower level of education. Pupils in the higher level of education (vwo) reported higher indifference points than those in the lower level of education (havo) for both delay intervals.

DISCUSSION

In this study we examined the developmental trajectory of temporal discounting during adolescence. We hypothesised that the rate of temporal discounting would

decrease with age, reflecting an increase in delay of gratification abilities. Furthermore, we assumed that this development would be influenced by individual differences, namely sex and level of education.

Our results showed a significant age-related change on a straightforward measure of general discounting behaviour, the area under the discounting curve (AUC). This indicated that for participants in the late adolescent group (16-17 years) the delayed reward lost its subjective value more slowly than for the early adolescent group in our sample (12-13 years). Examination of the influence of individual differences between adolescents showed that this age-related development was similar for both levels of education. However, pupils in pre-university education (vwo) showed consistently less discounting of future rewards across the three delay intervals than those in senior general secondary education (havo). This indicated that pupils in a lower level of education were more drawn to immediate rewards, and that the differences between the groups were quantitative not qualitative. No differences were observed between sexes.

Our additional analyses of individual indifference points clearly indicated the added value of examining indifference points in combination with area under the curve measures. The analyses using area under the curve measures showed that discounting behaviour decreased with age, but examination of indifference points showed that this development differs per delay interval as we hypothesised and as has previously been found in a comparison between adults and adolescents (Christakou, et al., 2011). For the week and month delay intervals, pupils enrolled in pre-university education, the higher level used in this study, consistently discounted the value of delayed rewards less than those in the lower level studied, senior general secondary education. However, only those in the lower level of education showed a decrease with age, indicating that their discounting behaviour became increasingly similar to that of the pupils in the higher level. In the case of the six-month delay interval, age-related decreases were again found, but these did not differ between the two educational levels.

Our finding of age-related changes in discounting behaviour concurs with the results of other studies, which previously reported differences in discounting

behaviour across the lifespan (Green, et al., 1994; Green, et al., 1999; Scheres, et al., 2006). In a previous study in adolescents, Steinberg and colleagues (2009) also found significant differences between young adolescents aged 13 and younger and older adolescents aged 16 and older. Both their data and our findings suggest that the period between 13 and 16 years of age may be important for the development of discounting behaviour, and therefore the preference for delayed versus immediate rewards. This shift in discounting behaviour towards a more future oriented perspective is paralleled by the continued development of the areas of the brain involved in temporal discounting and other future oriented behaviour (Casey, et al., 2011). A recent study by Chrisakou et al. (2011) showed that changes in activation in the limbic corticostriatal network in the brain, including the ventromedial prefrontal cortex, were associated with the previously reported age-related decreases in impulsive choices during adolescence. Other work has shown that less impulsive temporal discounting behaviour was associated with more mature patterns of white matter organisation in the lateral prefrontal and temporal and parietal areas of the brain previously implicated in discounting behaviour (Olson, et al., 2009). Interestingly, some of the reported associations were age-dependent, meaning that they likely reflect developmental processes, while others, particularly in the left temporal and right frontal regions, were age-independent. The authors speculate that these age-independent associations may reflect individual differences in discounting behaviour between adolescents. We identified one possible cause of these individual differences in our study, namely level of education.

The observed age-related changes may also be a result of older adolescents having experienced more temporal delays. This may lead to a more advanced subjective perception of a delay interval: a year may seem shorter to an older adolescent than to a younger individual who has less personal experience with opting for a delayed reward. Previous research in animals has shown that temporal discounting is influenced by familiarity with making decisions between delay intervals (Logue, Rodriguez, Pena-Correal, & Mauro, 1984).

Through our additional analyses of individual indifference points we were able to show that the developmental changes evidenced by area under the curve measures

did not occur for all indifference points. Though early and late adolescents may have similar indifference points when choosing between a delayed amount available next week or a smaller amount immediately, if the delay interval is increased to six months their decisions will differ. This could have behavioural implications that are relevant in educational settings. For example, passing end of year exams often relies not only on studying the week before the test, but on continuous work throughout the school year to ensure that the pupil is familiar with all concepts that are covered. Now imagine that two individuals are told that they need to study for an important test that they must pass, but are also invited to go to a friend's birthday party. When the amount of time between the test and the party is one week, both a 12 year old and a 16 year old individual may make a similar decision and decide to study. But if the delay interval is increased to a month their decisions may differ due to an age-related improvement in their decision-making abilities: the 16 year old may choose to study and the 12 year old may go to the party. Younger pupils may therefore benefit from assistance in making decisions regarding long-term planning.

A further advantage of the examination of individual difference points is demonstrated by our finding of an interaction between age and level of education. The conventional area under the curve analysis we initially performed showed that discounting behaviour improved with age and level of education. However, the analysis of individual indifference points showed that the improvement with age for the two shorter delay intervals only occurred among pupils with in the lower level of education. The discovery that pupils in a lower level of education showed steeper discounting, could be related to studies showing that higher intelligence is associated with lower levels of discounting (Shamosh, et al., 2008; Shamosh & Gray, 2008). This suggests that if a pupil's IQ determines the educational track they are enrolled in, lower IQ scores in our lower level of education may have resulted in the higher discount rates found in this group. However, the level of education variable used in our study is not only influenced by intelligence. In the Dutch educational system, pupils are placed a particular educational track based on ability, but also based on their academic achievement. This means that underachieving students may be placed in a lower track than their IQ warrants. Furthermore, research in college students has

shown that discount rates are also negatively correlated with academic achievement (K.N. Kirby, et al., 2005; Silva & Gross, 2004), suggesting that IQ may not be the sole cause of the higher discount rates in the lower level of education group. Further research including both IQ and achievement measures is needed to examine this relationship.

In contrast to the AUC measure, our analysis of indifference points also showed continued development of discounting abilities among pupils in the lower level of education compared to the higher level of education. Previous studies of delay of gratification abilities, have suggested that there is rank-order stability between individuals (Moffitt, et al., 2011). This has lead to speculation that the ability to delay gratification is a biologically based trait and that despite changes in all individuals over time, a child with relatively weak self-control will grow up to be an adult who finds it more difficult than others to delay gratification (Casey, et al., 2011). Our findings suggest that this may always not be the case, as with age the participants in the lower level of education become more similar in their discounting behaviour to participants in the higher level of education. This is in line with recent intervention studies, which suggest that the ability to delay gratification is malleable, and can be improved through training (Diamond & Lee, 2011).

Though we examined two levels of education, all participants in our study were enrolled in relatively high levels of education, which would enable to them to enter higher education at college or university level. This means that generalisation of results to other populations should occur carefully. However, the finding that the greatest development in discounting abilities across delay intervals occurred among pupils in the lower level of education used in our study indicates that larger developmental effects may be found if a less highly educated sample were examined.

In conclusion, our results confirm that there are age-related decreases in discounting of delayed relative to immediate rewards, which are influenced by individual differences between adolescents, such as level of education. Additionally, we have shown that the analysis of divergence in individual indifference points can provide additional information when used alongside traditional AUC and discount rate approaches.

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