Age and educational track influence adolescent discounting of delayed rewards

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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. This change was related to educational track. In the lower educational track, an age-related decrease in discounting was found for all three delay intervals. In the higher educational track this decrease only occurred for the 6 month delay interval. However, across all delay intervals enrolment in a higher level educational track was associated with an increased preference for long-term rewards. These results suggest that late adolescents are less susceptible than early adolescents to the competing presence of an immediate reward when making long-term decisions, a skill which becomes increasingly important as they transition into adulthood.

Keywords: temporal discounting, adolescence, age, development, educational track

INTRODUCTION

Adolescents are often characterized as impulsive and unable to plan ahead or envisage the long-term effects of their behavior. 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 behaviors (Reyna and Farley, 2006; Steinberg, 2008). Recently, these impulsive behaviors have been examined in adolescent samples using a behavioral paradigm known as temporal discounting (Olson et al., 2007; Olson et al., 2009; Steinberg et al., 2009; Christakou et al., 2011). 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; Rachlin et al., 1991; Green et al., 1994). Adolescents with a steeper rate of temporal discounting count the value of delayed rewards more steeply than a group of college students and a group of older adults. A subsequent study compared a single group of adolescents of diverse ages to groups of young or older adults. For example, Green et al. (1999) collected data from a group of young adolescents and found them to discount the value of delayed rewards more steeply than a group of college students and a group of older adults. A subsequent study by Scheres et al. (2006) examined changes during the adolescent as these skills may be vital to ensure a successful transition to adulthood.

Within a temporal discounting task, a participant often 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 and Green, 1995). The subjective value of the delayed reward for each time point is known as the indifference point, and is equal to the amount at which the participant finds the largest and smallest current reward of equal value (Myerson et al., 2001). In adolescents, higher rates of discounting have been found in specific groups such as smokers compared to non-smokers (Reynolds and Fields, 2012), and heavy drinkers compared to light drinkers (Field et al., 2007), as well being a characteristic of certain developmental disorders such as attention deficit hyperactivity disorder (Barkley, 1997) and conduct disorder (Anokhin et al., 2011).

A few studies have examined developmental changes in discounting behavior during adolescence. Initial studies often compared a single group of adolescents of diverse ages to groups of young or older adults. For example, Green et al. (1999) collected data from a group of young adolescents and found them to discount the value of delayed rewards more steeply than a group of college students and a group of older adults. A subsequent study by Scheres et al. (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, these studies used broad age ranges, and were therefore unable to examine if these changes occur across the entire adolescent age range, or are limited to a specific period in adolescent development. 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 behavior, such as sex and educational attainment, have previously been examined in adult samples. Higher income and education have been associated with lower discount rates (Harrison et al., 2002; Jaroni et al., 2004; De Wit et al., 2007). Discount rates have been shown to have a negative association with grade point average in university students (Silva and Gross, 2004; Kirby et al., 2005). Previous studies of sex differences have reported varying findings, making it difficult to draw overall conclusions on sex differences in discount rates (Kirby and Marakovic, 1996; Harrison et al., 2002; Silverman, 2003; Reynolds et al., 2006; Reimers et al., 2009; Steinberg et al., 2009). In adolescents, the effects of individual differences have not been studied extensively.

When taken together, the results of the aforementioned studies suggest that discounting behavior continues to develop during adolescence and may be influenced by individual differences. However, these studies have analyzed differences in discounting behavior by comparing only one general discounting metric such as the discount rate. Such metrics summarize intertemporal preferences measured across several delay intervals into one quantitative variable, and are therefore unable to indicate at which subset of the delay intervals the biggest changes occur. However, a recent study in adults and adolescents showed that differences between them in discounting behavior 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., 6 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 large sample comprising three age groups (12–13, 14–15, and 16–17 years) so that close evaluation of developmental trajectories is possible. Secondly, we aim to extend previous findings by examining differences in discounting behavior at three specific time points to see if behavior differs between the groups when the time between the immediate and delayed reward is a week, month, or 6 months. Developmental differences in 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 analyze the role of individual differences between adolescents, namely sex and educational track, on discounting behavior.

To this end, a large cross-sectional sample (N = 622) of Dutch secondary school pupils, enrolled in the two highest educational tracks, completed a temporal discounting task. We hypothesize that discounting rates will decrease with age, i.e., that participants will become decreasingly oriented toward immediate rewards. We expect that this change will differ between the different delay intervals. More specifically, we expect changes in discounting behavior 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 pupils enrolled in a lower educational track will report steeper discounting than those in a higher educational track. As previous research regarding sex differences in discounting behavior has been mixed, we included sex in our model without making a specific hypothesis about the expected direction of sex effects.

MATERIALS AND METHODS

PARTICIPANTS

The initial sample included 691 adolescents between the ages of 12–17 years, recruited within a larger research project examining adolescent cognitive development (e.g., Boschloo et al., 2012; Dekker et al., 2013). Data from this project concerning the influence of temporal discounting on academic motivation and achievement have been published elsewhere (Lee et al., 2012). 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. 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 (‘hooger algemeen vormend onderwijs’ or “havo”) or pre-university education (‘voorbereidend wetenschappelijk onderwijs’ or “vwo”). Pupils from the lowest educational track were not recruited for this study, due to the high rate of learning disorders and behavioral problems among this group, which could have confounded the results. The selected tracks...
constitute the two highest educational tracks within the Dutch system and approximately 40% of pupils are enrolled in one of these tracks. Students are placed in tracks based on their performance on national standardized tests at the end of primary school. Successful completion of senior general education enables the student to enrol at a university of applied science, which offers vocational training in subjects such as nursing, performing arts, and social work. Pre-university education offers entry to higher level programmes at research universities, such as medicine and law. Courses at these institutions are more research-oriented than those at universities of applied science, where courses are more practice-oriented.

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.

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 min, of which 5 min were spent on the temporal discounting task. All pupils who returned the information package were included in the testing procedure. 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 behavior. 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. Three interval lengths were used for the time between the immediate and delayed rewards: 1 week, 1 month, and 6 months. Choices were presented in three blocks: one per delay interval. Within each block choices were presented as separate items, and in ascending order of each of the values of the immediate reward. This resulted in 27 trials per participant. The week delay interval was presented first, followed by the month and 6 month intervals. 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.

The value of the delayed rewards were selected to closely resemble amounts the adolescents could realistically receive, as previous research has shown that the rate of temporal discounting is influenced by reward magnitude (Green et al., 1997). All rewards were hypothetical, as comparisons of tasks using real and hypothetical rewards have shown no difference in the results found (Johnson and Bickel, 2002; Madden et al., 2003, 2004). The delay intervals used in the task were chosen to reflect delay intervals adolescents were likely to have previously experienced when making decisions in real life.

ANALYSES

The area under the curve (AUC) method was used to calculate a measure of overall discounting behavior and enable comparison with previous studies. This approach is frequently used within experimental research paradigms (e.g., Dixon et al., 2003; Scheres et al., 2006; Olson et al., 2007) as it avoids the difficulties associated with methods based on theoretical discounting functions (Myerson et al., 2001). Participants’ indifference points were normalized, 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 normalized 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

Table 1 | Participant characteristics (following exclusion).

| Age       | Male:female ratio | Level of education | N  |
|-----------|-------------------|--------------------|----|
| Age 12–13 | 12.62 (0.49)      | 104:117            | 221|
| Age 14–15 | 14.36 (0.48)      | 104:148            | 252|
| Age 16–17 | 16.48 (0.50)      | 71:121             | 192|
| Total     | 14.39 (1.60)      | 279:386            | 665|
Table 2 | AUC and indifference points as a function of age and level of education.

|                  | Total sample | 12–13 years | 14–15 years | 16–17 years |
|------------------|---------------|-------------|-------------|-------------|
|                  | M (SD)        | M (SD)      | M (SD)      | M (SD)      |
|                  | Senior general education | Pre-university education | Senior general education | Pre-university education | Senior general education | Pre-university education |
| AUC              | 0.59 (0.26)   | 0.45 (0.26) | 0.62 (0.24) | 0.56 (0.25) | 0.62 (0.23) | 0.58 (0.26) | 0.64 (0.24) |
| Indifference point | 43.15 (8.42) | 39.05 (12.40) | 64.32 (8.59) | 44.95 (8.42) | 43.86 (7.87) | 43.86 (7.41) | 44.66 (5.78) |
| weekly           | 14.16        | 26.53 (16.46) | 36.32 (13.28) | 33.42 (14.32) | 36.54 (12.26) | 34.53 (14.03) | 38.13 (11.90) |
| monthly          | 20.34 (16.76) | 14.23 (14.57) | 21.46 (16.79) | 17.97 (16.21) | 21.52 (16.14) | 18.61 (16.98) | 27.47 (17.27) |

RESULTS

Participants who produced inconsistent discounting data \( N = 32 \) were excluded from further analysis, in line with methods used in previous studies (Reynolds et al., 2006; Olson et al., 2007). 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.

The results of the analysis did not differ when inconsistent discounters were included. However, for sake of clarity only the results of the analyses without these participants are reported in this paper.

ANALYSIS 1: AREA UNDER THE CURVE

A three-way ANOVA showed a significant main effect of age on the area under the discounting curve \( F(2, 622) = 7.667, p < 0.001, \) partial \( \eta^2 = 0.02 \), with post hoc tests indicating that participants in the youngest age group discounted rewards more strongly than those in the oldest age group \( p < 0.001 \). A significant main effect of educational track was also found \( F(1, 622) = 35.53, p < 0.001, \) partial \( \eta^2 = 0.05 \), due to stronger discounting by participants in the lower track, compared to the higher track (see Table 2). There was no significant difference in discounting behavior between boys and girls \( p = 0.86 \) and there were no significant interactions.

ANALYSIS 2: INDIVIDUAL INDIFFERENCE POINTS

Subsequently a repeated measures ANOVA was performed. Tests of within subject factors showed a significant main effect of delay interval \( F(1,1102.71) = 829.03, p < 0.001, \) partial \( \eta^2 = 0.57 \) with participantsdiscounting more strongly as the delay interval increased. A significant interaction was found between delay interval and educational track \( F(1,1102.71) = 7.47, p = 0.001, \) partial \( \eta^2 = 0.01 \), showing that pupils in the two tracks differed in their changes in discounting behavior over the three delay intervals. The interaction between delay interval, age, and educational track showed a trend toward significance \( F(1,1102.71) = 2.34, p = 0.06 \). No other significant interactions were found.

Tests of between-subject factors showed a significant main effect of age \( F(2,622) = 8.24, p < 0.001, \) partial \( \eta^2 = 0.03 \) and educational track \( F(1,622) = 31.83, p < 0.001, \) partial \( \eta^2 = 0.05 \), indicating that on average age groups and school types differed in their discounting behavior across time points. The main effect of sex was not significant \( p = 0.95 \). The interaction between age and education track showed a trend again toward significance \( F(2,622) = 2.73, p = 0.07 \). Other interactions were not significant.

Post hoc analyses week and month delay intervals

Findings from follow-up three-way analyses of variance for the week and month delay intervals found significant main effects of
In this study we examined changes in temporal discounting during adolescence related to age, sex, and educational track. Analyses using a single discounting metric, the AUC, showed that discounting decreased with age and educational track: participants in the early adolescent group and those in the lower educational track were more drawn to immediate rewards than those in the late adolescent group and the higher educational track. Thus for younger participants and those enrolled in a lower educational track, the delayed reward lost its subjective value more quickly than for older participants and those enrolled in the higher educational track. The examination of individual indifference points showed that for the week and month delay intervals, pupils enrolled in pre-university education, the higher educational track examined in this study, consistently discounted the value of delayed rewards less than those in the lower track studied, senior general secondary education. However, only those in the lower track showed a decrease with age, indicating that their discounting behavior became increasingly similar to that of the pupils in the higher level. In the case of the 6 month delay interval, age-related decreases were again found, but these did not differ between the two educational levels. No differences were observed between the 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 behavior decreased with age, but examination of indifference points showed that this development differs per delay interval. This was in line with our hypotheses, and similar to results previously found in a comparison between adults and adolescents (Christakou et al., 2011). Our finding of developmental changes in discounting behavior concurs with the results of other studies, which have previously reported differences in discounting behavior across the lifespan (Green et al., 1994, 1999; Scheres et al., 2006). In a previous study in adolescents, Steinberg et al. (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...
IQ is strongly related to educational track, there is also a group of previous research using Dutch pupils, which showed that although in a lower track than their IQ warrants. This was confirmed by pre-measures. This means that underachieving students may be placed in a particular educational track based on their academic achievement and not based on IQ. In the educational system, pupils are placed in a particular educational track based on their academic achievement and not based on IQ.

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. With increasing age, the participants in the lower level of education become more similar in their discounting behavior to participants in the higher level. This finding is in line with intervention studies which suggest that self-control is malleable, and can be improved, for example through training (Diamond and Lee, 2011). As our findings are based on a cross-sectional sample, it is unclear if these developmental changes would result in changes in the rank-order of discounting abilities with age. Alternatively, they could reflect an age-related decrease in discounting behavior.
in variance in discounting behavior, without affecting the rank-order of this ability. Previous studies have shown mixed support for the idea that self-control is a biologically based trait and that despite changes in self-control 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. While some studies have found evidence of heritability of discounting during adolescence (Anokhin et al., 2011; Mitchell, 2011), previous studies of the broader concept of self-control abilities have suggested that there is only a degree of rank-order stability of these abilities between individuals (Moffitt et al., 2011). More research, using longitudinal samples, is needed to examine the rank-order stability of discounting behavior in more detail.

A number of considerations in interpreting the current results should be mentioned. 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 generalization 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. Furthermore, we cannot exclude the possibility that the order of presentation of the items in the discounting task influenced the results. Previous research (e.g., Robles and Lee, 2013) has shown that the order of presentation of the items in a delay-discounting task may be found if a less highly educated sample were examined. However, we cannot expect the effect of order of presentation to differ between the groups, as the items in our study were only presented in ascending order, our results may have overestimated participants’ discount rates. However, as we do not expect the effect of order of presentation to differ between the groups, this should not have affected the observed group differences.

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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Lee et al. 2013| Volume 4 | Article 993 | www.frontiersin.org

December 2013 | Volume 4 | Article 993 | #7

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