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

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## SUMMARY

Adolescence is a period of physical, psychological and social transitions from childhood to adulthood. It is associated with a unique set of behaviours, resulting in the common view that adolescents are myopic risk-takers, who are unable to plan ahead or envision the long-term consequences of their decisions and actions. It is also a period of continued development of the cognitive and social-emotional systems in the adolescent brain. Changes in the areas of the brain that comprise the social-emotional system make adolescents highly sensitive to rewards, motivational cues and emotional contexts. At the same time, the still developing cognitive control system is often unable to influence the strong impulses of the social-emotional system. This makes adolescence a particularly interesting period to examine decision-making competence.

The aim of this thesis was to elucidate how adolescents make decisions and how developmental changes during adolescence may influence this. A general introduction to the thesis is provided in *chapter 1*.

*Chapters 2 and 3* examined an important aspect of adolescent decision-making, namely the development of delay of gratification abilities, as well as the real life consequences of this ability. *Chapter 2* describes how a sample of 622 Dutch adolescents aged 12 -17 years completed a temporal discounting task, which measures the preference for future versus immediate outcomes. 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). Age-related development, as well as the effects of individual differences in level of education and sex, was examined. The frequently used area under the curve (AUC) method for general analysis of the data was combined with an additional examination of the decisions made at each specific delay interval. Results using the AUC method 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. However, analysis of the individual delay intervals showed that the differences in decisions made by the two groups decreased with age for the shorter

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delay intervals (week and month). No differences were found between males and females. Our 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.

The differences found between students in the two levels of education studied in *chapter 2* suggest that the ability to delay gratification may have real-life consequences. This was examined in *chapter 3*, which investigated the relationship between temporal discounting and academic achievement in a large sample ( $N = 638$ ) of 12-18 year old adolescents. The mediating effect of academic motivation on this relationship was also examined. The same discounting task was used as in *chapter 2*, combined with a questionnaire examining academic motivation. End-of-year grades for three core subjects (Dutch, English and Maths) were also collected for all participants. These were combined to create a single measure of academic achievement. Results showed that students with an increased ability to delay gratification performed better academically than those less able to delay gratification, as evidenced by higher grades in the three core subjects. This relationship was mediated by academic motivation; effect of delayed gratification abilities on grades was most effective when academic motivation was high. These results suggest that delay of gratification abilities may be an individual difference variable that distinguishes the highest achieving students from their peers.

*Chapter 4* provides an initial examination of influences on emotional processing during adolescence, namely the effect of sex and pubertal status. Emotion processing is important component of adolescent decision-making, as the emotional aspects of decisions are often more salient in this age group than in childhood or adulthood. Furthermore, during adolescence social relationships become more important, and maintaining these relationships requires adequately processing social stimuli, such as facial emotions. The study described in *chapter 4* examined sex differences in emotional face processing during adolescence. Participants were  $N = 1951$  adolescents with a target age of 14, who completed a forced-choice emotion discrimination task comprising morphed faces that contained a blend of two emotions in varying intensities. Four morph progressions were used: Anger-Fear, Anger-Sadness,

Happiness-Fear and Happiness-Sadness. Results showed that adolescent girls showed faster and more sensitive perception of facial emotions than boys across all morph progressions. Both adolescent boys and girls were most sensitive to variations in emotion intensity in faces combining happiness and sadness, and least sensitive to changes in faces comprising fear and anger. Furthermore, both sexes overidentified happiness and anger. The overidentification of happiness was stronger in boys. These findings were not due to faster pubertal maturation in girls, since controlling for the level of pubertal maturation that participants had reached did not influence the results.

*Chapter 5* examined the role of an external influence on decision-making, namely the role of prior social information on decision-making during a trust game. Adolescents were divided into three age groups: early adolescents (12-13 year-olds), mid-adolescents (14-15 year olds) and late adolescents (16-18 year olds). Participants played an iterated trust game against three hypothetical partners they received prior social information about ('good' partner, 'bad' partner and 'neutral' partner). Participants were unaware that all three partners showed equal amounts of trustworthy behaviour during the game (70% share trials, 30% keep trials). Results showed that all participants were most likely to share with the good partner on initial trials and rate this partner as most trustworthy. Though this trust decreased as the task progressed, participants continued to trust and view the 'good' partner as more trustworthy than 'bad' and 'neutral' partners throughout the game. However, mid and late adolescents showed a larger decrease in trust of the 'good' partner than early adolescents. Thus, increased trust in the 'good' partner persisted in all age groups, despite all partners showing similar amounts of trustworthy behaviour. However, adjustment of behaviour was greatest in the two older groups. This suggests that the ability to overcome prior social information, and adapt decision-making behaviour in interpersonal trust situations, improves with age.

In *chapter 6* the influence of individual differences in the balance between emotional and cognitive systems on use of decision-making styles in was examined across various real-life situations. A sample of mid-adolescents aged 13-15 years, completed self-report questionnaires, which probed their sensation-seeking (related

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to development of the emotional system) and impulse control (related to development of the cognitive system). Additionally, they answered questions related to a number of decision-making vignettes. These vignettes described situations that required the participant to make a decision. Participants read the vignette and subsequently indicated for five decision-making styles how likely they were to make a decision in this manner. Results showed that self-reported levels of impulse control were more predictive of use of decision-making styles than the balance between sensation seeking and impulse control. High levels of impulse control were associated with increased use of the more mature, rational decision-making style. Investigation of sex differences showed that girls made more use of rational, intuitive and dependent styles than boys.

Finally, in *chapter 7* concluding remarks and the main findings of this thesis are presented in the context of current knowledge on adolescent decision-making. Implications and suggestions for future research are also discussed.