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CHAPTER

Concluding remarks

7

Adolescence is a period of major change in brain development and behaviour. Previous research has shown that this period is characterised by the continued development of both the cognitive and social-emotional systems in the brain (Casey, Getz, & Galvan, 2008; Steinberg, 2008). Hormonal changes during puberty in neurotransmitter levels in the limbic areas that comprise the brain's social-emotional system make adolescents extremely sensitive to motivational cues, such as rewards, and emotional contexts, such as the presence of peers (Somerville & Casey, 2010). The cognitive system, involved in the regulation of behaviour in order to perform goal-directed actions, improves steadily from infancy through to adulthood. However during adolescence, the cognitive control system is often unable to assert top-down regulatory control on the strong impulses of the social-emotional system (Steinberg, 2008). This makes decision-making a unique topic to examine during adolescence, as it has been suggested that adolescents are particularly prone to decision-making difficulties.

The main objective of this thesis was to examine how adolescents make decisions and how the balance between the cognitive and social-emotional systems in the adolescent brain influences this process. Furthermore, while adolescents are generally assumed to be poor decision-makers, there is a large amount of variability between individuals in their ability to make decisions during this period. Therefore, individual differences between adolescents were also examined. In this final chapter the findings of the previous empirical chapters are examined in light of the aims of this thesis. Implications of these findings, as well as suggested directions for future research, will be discussed.

DECISION-MAKING DURING ADOLESCENCE

The dual-process model of adolescent development suggests that adolescents are extremely sensitive to immediate rewards, thus making it difficult for them to delay gratification (Steinberg, et al., 2009). *Chapter 2* of this thesis shows that during adolescence the susceptibility to the presence of an immediate reward when making decisions decreases with age, especially during the early and mid adolescent periods. Adolescents are increasingly able to delay their immediate need for gratification in favour of the pursuit of their long-term goals. Recent neuroimaging studies have shown that the behavioural changes in delay of gratification abilities are accompanied by developmental changes in the brain (Christakou, Brammer, & Rubia, 2011; Olson, et al., 2009). More specifically, with age, activation increases in the ventromedial prefrontal cortex and ventromedial striatal activation decreases. Furthermore, functional connectivity between these areas increases with age and results in lower levels of discounting (Christakou, et al., 2011). This shows that with age the cognitive system becomes increasingly integrated with socio-emotional areas and is able to assert top-down control. As a result, adolescents are increasingly able to inhibit their preference for immediate rewards. This ability is of increasing importance as adolescents transition into adulthood, at which point they need to be able to make decisions independently. Furthermore, as is described in *chapter 6*, individual differences in impulse control predict use of deliberative and rational decision-making styles. The higher an individual's cognitive control, the more able he or she is to make mature, rational decisions.

In addition to the finding of continued development of discounting behaviour, *chapter 2* also shows that there are important individual differences between adolescents in their ability to delay gratification. Pupils enrolled in two tracks of the Dutch educational system, havo and vwo, were compared. Vwo pupils showed a greater preference for long-term rewards than havo pupils, and the difference between the two tracks studied decreased between ages 12 to 17. This finding demonstrates that not all adolescents are equally impulsive or responsive to rewards, and that delay of gratification abilities may be an important influence on academic outcomes.

The influence that the ability to delay gratification can have on real-life outcomes

is further illustrated by the findings of *chapter 3*, which shows that the more able adolescents are to delay gratification, the higher their academic motivation and achievement. Thus, the ability to delay gratification seems to be a skill that is of particular relevance to outcomes in educational contexts. In these situations adolescents are continually faced with decisions that require them to choose between attractive non-academic pursuits with immediate rewards (e.g. going out with friends, watching TV), or postponing gratification in favour of the long-term dividends offered by engaging in academic activities. As a result, students who are unable to resist the temptations offered by immediate rewards may be at risk of not realising their full academic potential.

The importance of delay of gratification abilities for successful development was also emphasised in a recent study by Casey and colleagues (2011). They were able to examine individuals (who participated in the seminal study by Mischel and colleagues (1989) described in the introduction of this thesis) 40 years after their delay of gratification abilities were assessed in childhood. As adults, these participants were divided in to two groups: high delayers, i.e. those participants who as children had been able to delay their gratification in the face of an attractive treat, and low delayers, i.e. those who failed to wait for the delayed reward and ate the treat. Both groups completed a go/no-go task to examine their impulse control abilities and sensitivity to reward. The study found that low delayers showed more activity in reward related areas, such as the ventral striatum, than high delayers. These findings suggest that the low delayers are more sensitive to reward than the high delayers, and that this may be a relatively stable difference from childhood through to adulthood (Carlson & Zelazo, 2011). Possible ways in which interventions could change this are discussed later on in this chapter.

In summary, *chapters 2, 3 and 6* show that decision-making develops during adolescence. Early adolescence is characterised by high levels of reward sensitivity and subsequently by a preference for immediate rewards. During adolescence the ability to wait for the delayed reward increases, in line with the continued development of associated networks in the brain (Christakou, et al., 2011; Olson, et al., 2009) As delay of gratification has been reported as a predictor of life outcomes in multiple

domains (Casey, et al., 2011; Moffitt, et al., 2011; Reimers, Maylor, Stewart, & Chater, 2009), knowledge of the development of this function may provide opportunities for intervention to protect adolescents from adverse developmental trajectories. These will be discussed in more detail later in this chapter.

IT'S NOT WHAT YOU KNOW, BUT WHO YOU KNOW: SOCIAL-EMOTIONAL INFLUENCES ON ADOLESCENT DECISION-MAKING

Decision-making does not occur in a vacuum. When making decisions, individuals are also confronted with their social environment, and with the consequences of their behaviour for the lives of others. Adolescents are particularly susceptible to social influences, as social relationships become increasingly important during this period. During the transition from childhood to adulthood, individuals spend an increasing amount of time with their friends (Brown, 2004). Developing successful relationships requires understanding the feelings of others, by reading emotional cues and modifying responses based on this information. During adolescence, prefrontal networks play an important role in using this emotional information to guide behaviour (Blakemore & Choudhury, 2006; Frith & Singer, 2008).

An important source of social information comes from facial expressions of emotions. People infer personality traits and social intentions from faces (Frith & Frith, 1999). These inferences are fast: judgments made after 100-ms correlate highly with those made without time constraints. This holds for judgments of trustworthiness, attractiveness, likeability, competence and aggressiveness (Willis & Todorov, 2006). *Chapter 4* shows that adolescents are able to judge facial emotions, though these judgments are sometimes biased towards certain emotions. When viewing faces comprising two blended emotions, adolescent girls showed faster and more sensitive perception of the emotions contained in these faces than boys. However, both adolescent boys and girls are most sensitive to variations in emotion intensity in faces combining happiness and sadness, and least sensitive to changes in emotions in faces comprising fear and anger. Furthermore, both sexes overidentify happiness and anger, meaning they will report these emotions as being dominant in faces where these emotions comprise less than 50% of the emotion blend. However,

the overidentification of happiness is stronger in boys. Though previous studies have reported sex differences in brain activation when viewing emotional faces (Killgore, Oki, & Yurgelun-Todd, 2001; Schneider, et al., 2011), behavioural studies have previously been inconclusive (Herba, Landau, Russell, Ecker, & Phillips, 2006; Thomas, De Bellis, Graham, & LaBar, 2007). However, these earlier behavioural studies may have suffered from lack of power, as sex differences in cognitive abilities are usually small but stable, requiring large sample sizes to detect these effects (McCarthy & Konkle, 2005). The study described in *chapter 3* used a sample of almost 2000 adolescents and therefore was able to demonstrate the presence of differences in emotion recognition between adolescent boys and girls.

Improved understanding of the emotions of others as described in *chapter 4*, is an important skill for successful social interactions. In *chapter 5*, decision-making within the context of social information was examined within a trust game paradigm. Previous studies have examined trust during adolescence in interactions with anonymous partners (Harbaugh, Krause, Liday, & Vesterlund, 2003; Sutter & Kocher, 2007; Van den Bos, Westenberg, Van Dijk, & Crone, 2010). The influence of social information on this type of decision-making has not previously been addressed. The results described in *chapter 5* indicate that prior social information about interaction partners influences subsequent decision-making behaviour. Participants made more 'share' decisions when playing a trust game against a partner they had received positive information about, then when they played a trust game against a partner they had received negative information about. Furthermore, this initial impression was persistent: though decision-making changed over the course of the game, the initial impression remained a strong determinant of participants' decisions on the final trials of the game. This effect was largest in the young adolescent group (12-13 years) when playing against the 'good' opponent. These results imply that the ability to overcome prior social information and adapt decision-making behaviour accordingly improves during adolescence. Nonetheless, initial social judgments remain influential, and young adolescents are particularly persistent in their belief in the trustworthiness of others.

METHODOLOGICAL CONSIDERATIONS

A number of methodological considerations pertaining to the studies described in this thesis warrant further discussion. Firstly, the task used in the studies described in *chapters 2 and 3* to measure temporal discounting. A new paper-and-pencil version was developed for these studies. This enabled collection of data from a large group of participants, which would not have been as feasible if a computerised task had been used.

The methods used to analyse the temporal discounting data form a second point of consideration. As is discussed in *chapter 2*, temporal discounting tasks offer detailed information about decision-making in the context of varying intervals between immediate and delayed rewards. However, most analysis methods condense the findings across delay intervals into a single discounting metric such as the discount rate (Rachlin, Raineri, & Cross, 1991) or area under the discounting curve (Myerson, Green, & Warusawitharana, 2001; Olson, Hooper, Collins, & Luciana, 2007). These metrics summarise intertemporal preferences into a single quantitative variable, which can be useful in studies where overall delay of gratification abilities are used to predict other outcomes. An example of this is given by *chapter 3* of this thesis, as well as by studies showing that the ability to delay gratification is related to a multitude of outcomes, such as socio-economic status, physical health, substance dependence and the tendency to smoke or gamble (Alessi & Petry, 2003; Bickel, Odum, & Madden, 1999; Casey, et al., 2011; Moffitt, et al., 2011; Reimers, et al., 2009; Reynolds & Fields, 2012). Nevertheless, by reducing delay of gratification abilities into a single variable, information about these abilities at specific delay intervals is lost. Yet these differences can be extremely informative when studying developmental changes. For example, a recent study comparing adults and adolescents showed that differences between these groups in discounting abilities became more apparent as delay intervals increased (Christakou, et al., 2011). *Chapter 2* of this thesis demonstrates that age-related changes in discounting abilities during adolescence vary per delay interval. This result could only have been found through analysis of individual points. Future developmental research could benefit from utilising this approach.

A third consideration is the use of designs involving hypothetical elements. The

temporal discounting task described in *chapters 2 and 3* used hypothetical monetary rewards and delays, and in *chapter 5* participants played a trust game against three hypothetical partners. In laboratory settings hypothetical approaches are often used as they have a number of benefits: experimental manipulations can be applied and non-experimental variables that may influence results can be controlled. However, there have been discussions about the ecological validity of these hypothetical approaches (Falk & Heckman, 2009; Steinberg, 2004). Studies examining the use of hypothetical delays and rewards in temporal discounting suggest that results do not differ from those using real delays and rewards (Madden, Begotka, Raiff, & Kastern, 2003; Madden, et al., 2004). Research on trust game performance suggests that individuals do make different decisions when playing against a real person or a computer, with participants sending less money to a computer than a real person (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). This suggests that the effects described in *chapter 5* may have been larger if the participants had played against real opponents. It seems that in the studies reported in this thesis, the advantages of the controlled designs that use of hypothetical approaches enabled, outweighed the disadvantages. However, it is important to consider the hypothetical nature of the studies when interpreting the results.

It has also been argued that laboratory studies of adolescent decision-making fail to consider the social and emotional contexts within which this behaviour occurs: are decisions made under conditions of low arousal comparable to those made under high levels of arousal (Gardner & Steinberg, 2005)? This question has previously been difficult to answer, as real-life levels of arousal are difficult to create in the lab. Interesting advances in examining this question have recently been made by studying decision-making in the presence of peers (Gardner & Steinberg, 2005). Studies have now shown that the presence of peers alters decision-making behaviour by increasing the salience of rewards (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Pfeifer, et al., 2011), making this an interesting design for future adolescent research.

PRACTICAL IMPLICATIONS

As has been described in this thesis, decision-making abilities continue to develop

during adolescence and are related to academic achievement. This implies that within the adolescent period some individuals will find it more difficult than others to resist the temptation of immediate rewards with adverse effects on their educational outcomes. Yet, in recent years the educational system in many countries in Western Europe increasingly requires students to actively manage their own learning. This is particularly so for the current educational system in the Netherlands, where a strong emphasis is placed on knowledge acquisition through active and independent learning under teachers' supervision, as opposed to knowledge transfer through traditional classroom teaching. This obliges students to work independently and supervise their own learning process. This means that those students who find it difficult to inhibit their tendency towards non-academic immediate rewards, may also find it difficult to actively prioritise learning activities which require long-term investment. The finding that the ability to delay gratification continues to develop during adolescence is therefore a significant finding for both educators and parents, and suggests a possible determinant of academic underachievement.

This finding also suggests two possible routes for intervention in educational settings. The first route involves actively improving delay of gratification abilities in low achieving students, for example through teaching goal-setting strategies encouraging students to work towards long-term goals. Alternatively, schools could choose to work with students' preferences for the short-term, by offering them more immediate incentives related to their academic performance. The latter option has been piloted in schools in the United States where students are offered financial incentives for improving their grade point average. This approach is controversial due to both the financial implications and the suggestion that a focus on short-term rewards can undermine intrinsic motivation to learn (Deci, Koestner, & Ryan, 2001). The first route, intervening to improve delay of gratification abilities, seems more promising. Firstly, previous research in children has suggested that self-control abilities are malleable and can be improved over time (Diamond & Lee, 2011). Secondly, as has previously been noted in this chapter, an improved ability to delay gratification is related to a multitude of positive lifelong outcomes and personal growth, suggesting that improvements in this ability can have effects beyond just

improvements in educational attainment. As a result, research has shown that the economic return of childhood and adolescent interventions is high, by enabling skill development that the individual continues to benefit from during adulthood (Heckman, 2006). And finally, the finding reported in *chapter 6* that impulse control is related to use of rational decision-making, suggests that interventions aimed at increasing impulse control and encouraging students to work towards long-term rewards may also aid their ability to make decisions in a rational and considered fashion. When designing this intervention the influence of the trust adolescents have in the person teaching the intervention needs to be considered. As is described in *chapter 5*, first impressions are persistent and influence the decisions subsequently made by adolescents, particularly early adolescents.

FUTURE DIRECTIONS FOR ADOLESCENT RESEARCH

The continued development during adolescence of both social-emotional areas and those involved in cognitive control suggests that decision-making changes during adolescence. This thesis has shown that this development is indeed paralleled by specific behavioural changes, and these changes, in turn, are influenced by individual differences in developmental trajectories between adolescents. These findings demonstrate that the integration of results from the various disciplines involved in adolescent research provides a more comprehensive view of this complex period in human development. This suggests that future adolescent research could benefit from further use of multidisciplinary approaches.

Much research on adolescent development has been centred on elucidating determinants of problem behaviours such as risk-taking and immature decision-making, against a background of adolescents' growing responsibility for their own behaviour. This fits within the disease model of human functioning that seems to be a dominant influence on current psychological and medical research. As Martin Seligman (2002), former president of the American Psychological Association has stated, in the past 50 years psychology has focused on "assessing and curing individual suffering" at the expense of studying "strength and virtue" (p. 4). This has led to a research field dominated by a focus on illness and prevention (Rich, 2003).

The World Health Organisation currently defines health as “complete physical, social and mental wellbeing” (p. 1; WHO, 2006), a definition that due to its absoluteness suggests that most individuals are unhealthy most of the time and contributes to the medicalisation of society (Huber, et al., 2011). This has led to a recent proposal to change the emphasis in this definition towards the ability to adapt and self-manage in the face of social, physical and emotional changes.

By solely focussing on those adolescents for who adolescence is a turbulent time, we forget about those who blossom from dependent children into independent, happy and responsible adults. Adolescence is in essence a transitional period. Individual differences between adolescents, in behaviour, brain maturation and social environment, shape this period into unique developmental trajectories for each individual. Enabling adolescents to transition safely into adulthood is of course of vital importance and any research that may support this should be continued. Examination of why some adolescents show dangerous levels of risk-taking while others do not, may reveal skills that could be stimulated in the latter group, for example through support from parents, teachers and other adult role models.

Furthermore, not all adolescent risk-taking is problematic or dangerous. Low level risk-taking is also the cause of the willingness adolescents often demonstrate to try new things, to explore and discover the world around them. And while adolescents’ lack of cognitive control may sometimes pose problems in decision-making contexts, it also gives them the cognitive flexibility to think creatively and ‘outside the box.’ Adolescence should thus be viewed as a period of unique opportunities for self-development, supported by the biopsychological and psychosocial changes the individual goes through. The challenge for future adolescent research will be to find ways to inspire and motivate adolescents to harness their creative abilities and youthful exuberance in the direction of positive life course trajectories.

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