Book Chapter for Social Dilemmas: New Perspectives on Reward and Punishment

Social decision-making in childhood and adolescence

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Abstract

This chapter describes several novel lines of research, which have focused on social decision-making and perspective taking across childhood and adolescent development using experimental games. We summarize results from developmental studies using variations of the Dictator Game, the Ultimatum Game, and the Trust Game. A special focus is given to the way cognitive control and perspective taking are implicated in social decision-making, and how these skills develop across adolescence. In addition, we describe insights from cognitive neuroscience studies concentrating on the role of brain regions important for cognitive control and perspective taking, such as the dorsolateral prefrontal cortex (DLPFC) and the temporal parietal junction (TPJ), in social decision-making in children, adolescents and adults. Together, the studies demonstrate a consistent pattern of both increasing strategic motivations and other-oriented concerns in social decision-making across development, which is confirmed by emerging contributions of DLPFC and TPJ. The combination of brain and behavior measures has the advantage of allowing for a deeper understanding of the separable processes involved in the emergence of advanced forms of social decision-making.

1.1 Adolescence as an important time for social-affective changes

Adolescence is a time of significant social-cognitive and affective changes, and encompasses several social challenges such as developing intimate friendships and gaining peer status (Dahl, 2004; Steinberg et al., 2008). This period is defined as the developmental phase between childhood and adulthood and spans from approximately ages 10 to 20 years. It starts with puberty, during which rising hormone levels trigger a cascade of physical and social-emotional changes, with different time courses for boys and girls (puberty starts approximately 1.5 years earlier for girls than for boys), and with the goal of preparing adolescents for later independence (Shirtcliff, Dahl, & Pollak, 2009). Puberty is followed by mid- to late adolescence, during which adolescents gradually attain mature social goals and eventually reach the legal age for adult responsibilities, such as drinking alcohol, financial independence, voting or getting a driver's license (Steinberg, 2008).

Several studies have reported that during adolescence there is a great improvement in mastery of many cognitive skills, such as the ability to keep multiple pieces of information in working memory (Luna, Padmanabhan, & O'Hearn, 2010), the ability to flexibly switch between multiple tasks (Crone, Bunge, van der Molen, & Ridderinkhof, 2006) and the ability to inhibit impulsive actions (Durston et al., 2006). These developmental improvements have been captured under the umbrella term 'executive functions', which refers to the ability to keep relevant information online and irrelevant information out of mind in order to achieve long-term goals (Huizinga, Dolan, & van der Molen, 2006).

At the same time, however, it is well documented that during adolescence there is a myriad of changes in decision-making processes which are particularly sensitive to social context, such as increased risk-taking in the presence of friends (Gardner & Steinberg, 2005) and increased sensitivity to social rejection (Cillessen & Rose, 2005; Sebastian, Viding, Williams, & Blakemore, 2010). These developmental sensitivities to affective and social contexts lead to an intriguing paradox in adolescent development. That is to say, under some circumstances, adolescents are compliant, smart, and have the capacity to think about innovative and creative solutions for complex problems, and to think about problems from multiple perspectives. However, under other circumstances, adolescents can react impulsively, without thinking about future consequences of their actions, and show intensified reactions to emotional and social situations. This imbalance is thought to result in several advantages such as explorative learning and adaptive sensation-seeking, but can also lead to serious health problems such as drug abuse, delinquency or social withdrawal (Crone & Dahl, 2012).

Given the strong interplay between cognitive and social-affective development, adolescence is a very important transition period for the development of social values and concern for others. The development of social perspective taking is one of the core milestones in human development. Perspective taking is defined here as the ability to understand intentions and goals from a third-person point of view, and the core components mature before the age of 5 years during which children develop a 'theory of mind' (Wellman, Cross, & Watson, 2001). However, after the age of 5 and particularly during adolescent development, there are continuous changes in how children and adolescents understand and consider intentions of others in social interactions. For example, recent experimental studies have shown that the basic ability to view a situation from the perspective of another person continuous to develop in adolescence (Dumontheil, Apperly, & Blakemore, 2010). This is not surprising, given that adolescence is a period with pronounced changes in social orientation and it is likely that many of adults' norms and heuristics in social decision-making are being shaped during adolescence.

The links between cognitive and social development and their specific importance during adolescence have been emphasized already in traditional developmental theories. Selman's (Selman, 1980) work particularly sheds light on the development of perspective taking and social cognitive abilities during adolescence and focuses particularly on the role of friendships in developing interpersonal understanding. According to his model, friendships are perceived from an egocentric perspective in early childhood; friends are playmates defined by proximity and have no personal thoughts and feelings (Level 0, undifferentiated, ages 3 to 7). The child grows to understand that others have needs and thoughts other than his/her own, but there is no merging and coordination of perspectives (Level 1, unilateral, ages 4 to 9). Due to major cognitive development, the child gains the ability to reflect on his/her behavior as perceived by others and thus recognizes the reciprocity of relationships but cannot yet perceive all perspectives simultaneously from a third-person perspective (Level 2, reciprocal, ages 6 to 12). It is in the next stage that the adolescent can take all perspectives simultaneously and perceive the dyadic relationship between him/her and the interaction partner as an outsider (Level 3, mutual, ages 9 to 15). Finally, the friendship can be recognized as a long-term interdependence and as a dynamic relationship with aspects of dependence and autonomy (Level 4, interdependent, beyond age 12). This framework facilitates the understanding of the development of interpersonal cognition as described by social information processing models (Crick & Dodge, 1994).

This chapter describes several novel lines of research, which have focused on the development of social decision-making and perspective taking using social dilemma games. These games are particularly informative in studying core components of social decision-making, such as acting upon social norms, fairness considerations, strategic bargaining, trust and reciprocity. We will summarize these recent insights by focusing on variations of the Dictator Game, the Ultimatum Game, and the Trust Game. A special focus is given to the way perspective taking and cognitive control are needed in social decision-making across adolescence, and how this development takes place.

The current chapter will also describe how social decision-making has been approached from a cognitive neuroscience perspective (Blakemore, 2008). One of the values of a cognitive neuroscience approach is that is allows us to examine how different brain areas contribute to different aspects of decision-making, thereby aiding in the process of dissociation of several subcomponents of decision-making, as well as their developmental trajectory. We will first introduce the current models of social brain development before moving to the development of social decision-making.

1.2 Models of social brain development

Social neuroscience theories have suggested that social decisions made by adults are the result of at least two interacting systems: an emotion-inducing system, which activates primary emotions, and an emotion-regulating system, which is an evolutionarily younger system that distinguishes humans from other animals (Adolphs, 2003; Gallagher & Frith, 2003). The emotion inducing system, which includes several regions such as the insula, the striatum and the amygdala, is involved in a quick detection of emotional context. The emotion regulating system allows individuals to control impulses, mentalize about intentions of others and take other people's perspectives, and relies on frontal-cortical areas, including lateral and medial prefrontal cortex (PFC) and on the temporal cortex, including the temporal parietal junction (TPJ) (see Figure 1). Prior research has shown a dynamic interplay between these brain regions when making social decisions (Rilling & Sanfey, 2011).

Only recently researchers have started to examine the development of neural regions involved in social dilemma tasks. The development of social information processing in general has previously been interpreted in the context of the Social Information Processing Network (SIPN) model (Nelson, Leibenluft, McClure, & Pine, 2005). The SIPN model suggests that social information processing results from three interacting neural 'nodes', a detection, affective and regulation node. The detection node, which comprises the intraparietal sulcus, superior temporal sulcus (STS), fusiform face area and temporal and occipital regions, detects social properties of a stimulus and is functionally mature before adolescence. The affective node, which includes limbic areas of the brain including the amygdala, ventral striatum, hypothalamus and orbitofrontal cortex, processes the emotional significance of a social stimulus and influences the behavioural and emotional responses to social stimuli. This node is particularly active in early adolescence, possibly under the influence of gonadal hormones. Finally, the cognitive-regulatory node, which consists of the PFC, is important for goal-directed behaviour, impulse control and theory of mind. The latter node is thought to have a gradual and slow developmental trajectory and continues to develop throughout adolescence, and recent studies suggest a similar developmental trajectory for the TPJ (Crone & Dahl, 2012).

These brain regions will be discussed and their developmental patterns will be described in the context of several social dilemma tasks. This integrative approach of combining social experimental, developmental and neuroscience research fields will lead to a new view on the development of social decision-making. In the sections below, for each process we will start with a description of behavioral changes in adolescence on specific social dilemma tasks (1) followed by a section on neural regions involved and their developmental patterns (2).

2.1 The development of fairness considerations

When making social decisions in which there is a division of goods between two individuals, two motivational aspects are important: interest in your own benefit and concern for others (Van Dijk & Vermunt, 2000). Over the past decades much research has been conducted to understand the emergence of a sense of fairness across development and in different contexts. Here, we discuss the developmental patterns based on studies employing several experimental investigations of fairness considerations based on the following games, which are described in the order of their complexity: the Dictator Game, the Standard Ultimatum Game, the Mini Ultimatum Game, and the Hidden Ultimatum Game.

The Dictator Game

The Dictator Game (DG) is a simple two-player bargaining game, in which an allocator decides how to split a certain stake (for example, 10 coins). The recipient does not have the possibility to reject the offer made by the allocator, so the proposed division is always divided as suggested by the allocator. It is thought that this game captures an objective indication of the fairness orientation of the allocator (Van Dijk & Vermunt, 2000).

Studies that have compared DG donations in children (as young as 3-6 years), adolescents and adults show that participants of all age groups typically share part of the goods with others (e.g., 20-30%), indicating that they express a concern for the outcomes of others, but they typically do not share half of the goods (50%), indicating that they keep most of the stake for themselves when the recipient has no power (Benenson, Pascoe, & Radmore, 2007; Gummerum, Keller, Takezawa, & Mata, 2008; Harbaugh, Krause, & Vesterlund, 2007). The preference for equity (i.e., an equal split of goods), relative to a split which is better for self or a split which is better for the other player, increases between ages 3-8 years (Fehr, Bernhard & Rockenbach, 2008). At the age of approximately 8-9-years children no longer differ from adults in their DG donations to others (Harbaugh et al., 2007). Together, these studies suggest that a basic understanding of fairness is already present in early childhood and that fairness concerns develop before early adolescence (ages 8 to 9).

The Standard Ultimatum Game

The Standard Ultimatum Game (UG) is a more complex version of the DG, where the first player (i.e., the proposer) makes an offer to divide a certain stake, for example 10 coins, between the two players. The second player (i.e., the responder) can either accept or reject the proposed division. If the offer is accepted, the coins are divided according to the offer. In case the responder rejects the proposed offer, both players receive nothing (Güth, Schmittberger, & Schwarze, 1982). Thus, this game captures not only fairness, but also strategic motives, because the proposer will make an offer which he believes will be accepted by the responder.

Developmental studies have demonstrated that children between ages 7-10-years make lower offers compared to older adolescents and adults (Harbaugh, et al., 2007). Interestingly, children already value equal distributions under the age of six, evidenced by the fact that they do reject unfair offers (Blake & McAuliffe, 2011; Harbaugh, et al., 2007; Takagishi, Kameshima, Schug, Koizumi, & Yamagishi, 2010). However, the development of strategic behavior develops quickly between pre-adolescence (7-10-years) and continues to develop during mid- to late adolescence and adulthood, such that adolescents and adults offer strategically more in the UG than in the DG.

That is to say, the DG is often contrasted with the Standard UG in order to have a better understanding of developmental changes in true fairness considerations (DG behavior) and strategic fairness considerations (UG). A recent study that made this comparison showed that children aged 6-13-years did not differ from each other in DG offers. However, in the UG an obvious developmental difference appeared: with age there was an increase in the amount of coins offered by the proposer (Steinbeis, Bernhardt, & Singer, 2012). The increase in UG offers with increasing age is also reported in several other studies that have compared children with adolescents, or children with adults (Blake & McAuliffe, 2011; Blake & Rand, 2010; Harbaugh, et al., 2007). These findings have been interpreted as an increase in strategic intentions and perspective taking during late childhood and adolescence (Crone & Dahl, 2012).

Steinbeis et al. (2012) explained this developmental pattern in terms of an increase in cognitive control. The researchers asked participants to complete the Stop Signal Task in the same experimental setting. This is an inhibitory control task in which participants need to withhold a motoric response when a target changes color. Intriguingly, the individual differences in cognitive control correlated with individual differences in strategic behavior (UG vs. DG). This led to the conclusion that the development of strategic bargaining is possibly associated with a developmental increase in the ability to inhibit selfish impulses.

In summary, even though there is no obvious developmental difference in DG offers in adolescence, strategic fairness considerations as measured in the UG show consistent developmental changes. The largest transition takes place between age 7 and 13 but changes continue to emerge also between childhood and adulthood (Harbaugh, et al., 2007; Leman, Keller, Takezawa, & Gummerum, 2008; Steinbeis, et al., 2012). Based on these prior studies, we hypothesize that two processes contribute to this developmental changes, an increasing ability to control impulses (Steinbeis, et al., 2012) and an increase in perspective taking. The latter process has been studied in the DG and UG using several manipulations, which are described in more detail below.

The Mini UG

The Mini-UG is a simplified version of the UG consisting of four conditions (Falk, Fehr, & Fischbacher, 2003). In each condition the proposer has a set of two fixed distributions to choose from; the responder can again either accept or reject proposed offers. The four conditions each contain the same unfair distribution of the stake (namely the 8/2 distribution with 8 coins for the proposer and 2 for the responder). In each of the four conditions the alternative division varies: 1) a hyper-fair condition (2/8; 2 coins for the proposer and 8 for the responder), 2) a fair condition (5/5), 3) a hyper-unfair condition (10/0; 10 coins for the proposer and none for the responder), 4) a no alternative condition (8/2 versus 8/2) (see Figure 2A for an example of conditions 1, 2 and 4).

Güroğlu, van den Bos, & Crone (2009) described 3 experiments: proposer mini-DG, proposer mini-UG, and a responder mini-UG with the aim of providing insight in how fairness considerations, intentionality and strategic thinking develop across adolescent development. The outcomes of the proposer mini-DG once again confirmed the lack of developmental differences between 9-, 12-, 15-, and 18-year olds; consistent with prior studies. The outcomes of the second experiment, proposer mini-UG, showed that, even though strategic behavior was already present at the age of 9, a developmental difference was observed in bargaining behavior in the DG versus the UG. That is to say, in the hyper-fair condition the 9-, and 12-year-olds made the same offers in both DG as UG, whereas 15-, and 18-year-olds made a clear distinction between the 2 games, which manifested itself in higher offers (more 2/8 offers) in the UG. Finally, results of the responder mini-UG demonstrated that intentions of proposers behind unfair offers were not taken into account in 9-year-olds, whereas from the age of 12 onwards, the rejection rates were influenced by the different options that were available to the proposer. For example, adolescents rejected unfair offers more often when the proposer had a fair distribution as alternative compared to when the proposer had no alternative. Together, these results were taken as evidence for increased perspective taking in adolescence which resulted in more strategic bargaining.

The Hidden Ultimatum Game

A second useful paradigm to make a distinction between altruistic and strategic considerations is the Hidden Ultimatum Game (Van Dijk, De Cremer, & Handgraaf, 2004). Hidden information means that the responder is only informed about a part of the information that is proclaimed to the proposer, whereby the proposer has the ability to use this additional information in his/her own advantage. For example, it can be the case that the proposer has 10 coins to share with the responder, but the responder thinks that there are only 8 coins in the game, and this condition is contrasted with conditions in which there are 10 coins to share with the responder, which is known by both parties (see Figure 2B for an example trial).

In case of complete information conditions where all information is visible to both parties, offers increased with age (Overgaauw, Güroğlu, & Crone, 2012): an outcome that is consistent to those reported for the standard UG. In contrast, when the proposer makes an offer in case of hidden information conditions, he/she might be considering the following two options: 1) making an honest and thus *truly* fair offer based on the total number of coins available (e.g., an offer of 5 coins in this case) or 2) making a lower offer based on the number of coins visible to the other player and thus maximizing his/her outcome. This additional information provides the proposer with the opportunity to act with a focus on self-interest maximization where at the same time he/she can make an offer that is *seemingly* fair (e.g., offering 4 coins in this case and keeping the two extra coins for him/herself) (Van Dijk, et al., 2004).

Our findings show that the preference for enlarging own outcome by concealing the hidden information is already present in children. Even children from the age of 8 are able to act strategically by using information of hidden coins in their own advantage (Overgaauw, et al., 2012). However, we also found clear differences between children and adults. Children showed only a small decrease in the number of coins offered in the hidden information conditions compared to offers in complete information conditions. Adults, on the contrary, showed a clear distinction between the different conditions by making higher offers in complete information conditions. In other words, in the hidden information adults behave in a self-interested, thus strategic way, and make lower offers.

In sum, investigations of several variations of the UG show that there is more self-oriented bargaining behavior before the age of 8 years and increasing understanding of strategic behavior during adolescence. Together, these studies suggest that cognitive control and perspective taking may be important components of the development of fairness considerations, such that adults inhibit selfish impulses and show more intentionality understanding.

2.2. Neural substrates of fairness considerations

Neuroscientific analyses of the standard UG show that an emotion-area, the insula, and a regulation area in the PFC, the dorsolateral (DL) PFC, were active when participants experienced unfair decisions by their interaction partners (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). The insula has previously been implicated in primary emotions such as disgust, whereas the DLPFC has been implicated in goal-directed cognitive control (Rilling & Sanfey, 2011). In the study reported by Sanfey et al. (2003), the insula was more active when recipients rejected unfair offers, reflecting the potential emotional basis for rejecting unfairness. In contrast, DLPFC was active when recipients rejected *and* accepted offers, possibly reflecting the cognitive basis of accumulating money. This difference was only observed when participants were playing with another person, and not when they were playing with a computer, emphasizing the social nature of this effect.

The importance of the DLPFC for the cognitive goal of accumulating money was confirmed using transcranial magnetic stimulation (TMS) studies, by showing that temporally altering neuron firing in this region results in an increase in acceptance of unfair offers in humans (Knoch, Pascual-Leone, Meyer, Treyer, & Fehr, 2006). Interestingly, a decision-making game which focused on cooperation rather than rejection (The Prisoners Dilemma Game) demonstrated that the nucleus accumbens, a region in the limbic area which is traditionally associated with reward sensitivity, is more active following mutual cooperation (Rilling, Sanfey, Aronson, Nystrom, & Cohen, 2004). Thus, rejection of unfair proposals and cooperation seem to depend on the same neural mechanisms as those that are sensitive to basic emotional signals of disgust and reward.

A developmental neuroimaging study that compared the UG with the DG for which the behavioral data were described earlier showed that children aged 6-13-years activated DLPFC when playing the UG as proposer, but this activation was stronger for the older children (Steinbeis, et al., 2012). The extent of this activation correlated with both performance on the Stop Signal Task and strategic behavior (higher offers in UG compared to DG), leading to the conclusion that the development of impulse control is an important component in the development of strategic fairness.

Güroğlu, van den Bos, van Dijk, Rombouts, & Crone (2011) reported partly overlapping findings when they asked children, adolescents and adults to play the mini-UG as responders in the scanner. Consistent with their prior behavioral report (Güroğlu et al., 2009), children rejected unfair offers as often in the condition in which the first player had no alternative as when the first player had a fair alternative, whereas adults rejected unfair offers much less often in the no-alternative condition compared to when there was a fair alternative. In addition, when rejecting unfair offers in the no-alternative condition, adults showed activation in DLPFC and TPJ, regions previously associated with impulse control and perspective taking, respectively. This activation was less extensive in children and emerged across adolescent development (Güroğlu et al., 2011).

Together, these studies demonstrate that social decision-making is regulated by both emotion-inducing and emotion-regulating brain areas, which make independent contributions to the decision process. These different brain areas have separable developmental time courses, with a relatively slow development of brain areas implicated in impulse control and perspective-taking, such as the DLPFC and the TPJ.

3.1 The development of trust and reciprocity

The different UG versions described above allow us to study fairness and self-interest in a simple experimental setting. However, in real life one often needs to make decisions about fairness based on whether one can trust the other person that they will reciprocate actions of fairness. These situations put high demands on our ability to think about the other person's intentions (or to take another person's perspective). A task that captures the essentials of trust and reciprocity is the Trust Game (TG) (e.g., Malhotra, 2004; Snijders, 1996; Snijders, & Keren, G., 1999). In this game two players are paired with each other as decision-makers (a trustor and a trustee) over single or numerous trials. The trustor typically makes the first decision, and the trustee observes the trustor's decision before making his/her own decision. More specifically, the trustor can choose between two options: a certain monetary outcome (the "no trust" option), in which both players receive a small reward (e.g., both receive 5 euros), and an uncertain choice (the "trust" option). When the trustor opts for the trust option, the trustee can choose between two options. Either the trustee decides to reciprocate trust, in which case both receive a relatively large reward (e.g., the trustor receives 18 euros and the trustee receives 22 euros) or the trustee decides to defect trust, in which case the trustor receives almost nothing (e.g., 1 euro) and the second player receives a large reward (e.g., 39 euros). The TG is a task that is very suitable to capture the risk to trust on the one hand, and reciprocity or defection on the other hand (see Figure 2C for an example).

Developmental studies using the TG showed that trust increases in early adolescence (van den Bos, Westenberg, van Dijk, & Crone, 2010), but most importantly, there is a protracted development of risk-dependent reciprocity. That is to say, when the trustor takes a large risk by trusting the trustee (for example, the trustor may lose a lot when the trustee defects trust), adults typically reciprocate more often than when the trustor does not take a risk (see Figure 2C for an example). This pattern suggests that in order to generate positive reciprocal exchanges, or realise "positive reciprocity" (McCabe, Houser, Ryan, Smith, & Trouard, 2001), it is necessary to take a risk or be vulnerable in favor of greater postponed gains from mutual cooperation.

In the study by van den Bos et al. (2010), children aged 9-10-years did not yet demonstrate this risk senstivity, and across adolescent development (12-22-years) this risk sensitvity slowly emerged (van den Bos, et al., 2010). These findings can be interpreted in the context of slowly emerging perspective taking skills, which increasingly play a role in adolescents' decisions in social interactions. Taken together, the number of studies using the TG to study developmental differences in trust and reciprocity is still relatively small, but studies consistently report a developmental increase in trust and reciprocity in early adolescence, with an increased contribution of perspective taking in later adolescence and early adulthood.

3.2 Neural substrates of trust decisions

Neuroscientific studies using the TG have demonstrated that in adults, the decision to trust is associated with increased activation in medial PFC when the interaction partner is a human compared to a computer (McCabe, Houser, Ruan, Smith, & Trouard, 2001). Medial PFC is a brain region that is active when individuals think about the mental states of others as well as their own state of mind, or when there is a need to explain and predict behaviours of others by attributing independent mental states, such as thoughts, beliefs and desires (Adolphs, 2003). Several neuroimaging studies have also reported increased activation in medial PFC for social cooperation (Rilling et al., 2002), competition (Gallagher, Jack, Roepstorff, & Frith, 2002), and moral judgement (Greene, Nystrom, Engell, Darley, & Cohen, 2004). Therefore, the medial PFC may have a more general role for predicting future outcomes of interactions.

When adult participants played the TG as trustees, they showed activation in a different set of brain regions, namely in DLPFC and TPJ, regions previously associated with impulse control and perspective taking (van den Bos, van Dijk, Westenberg, Rombouts, & Crone, 2009). Furthermore, a developmental study demonstrated that the extent of activation in these areas increases across adolescence. Notably, activation in these areas also correlated with individual differences in risk sensitivity, reinforcing the notion that these regions are important for perspective taking (van den Bos, van Dijk, Westenberg, Rombouts, & Crone, 2011).

Thus, the neuroscientific studies on the TG provide a highly comparable set of results as what emerged from the UG studies. Receiving unfair offers and receiving trust in one-shot dilemma games results in increased activation in DLPFC and TPJ, which was interpreted in the context that both processes require perspective taking and cognitive control. Indeed, activation in these regions correlates with behavioral measures of perspective taking and comes increasingly online during adolescent development (see also Crone & Dahl, 2012).

4.1 Repeated interactions

One-shot interactions are crucial for the elicitation of a clean measure of social preferences, i.e. other-regarding motives aimed at increasing or decreasing another individual's welfare (Fehr, 2009). However, social interactions in our daily lives are rarely single encounters. The following section shows that repeated interactions in social dilemma games are a useful method to gain further insights on developmental changes in social learning, e.g., how adolescents learn to deal with negative social experiences, such as ruptured cooperation or social exclusion.

Learning to bargain

Adult UG bargainers adjust their behavior to their interaction partners' responses and take into account information about what kind of proposals future interaction partners might accept or reject (Duffy & Feltovich, 1999; Fehr & Fischbacher, 2003). Harbaugh et al. (2007) examined the development of these tendencies by investigating how children and adolescents (ages 8-18) learn to bargain in a repeated UG. The experiment consisted of two treatments in which a proposer interacted with five different responders successively in either: 1) a "limited-information" treatment during which participants could learn about the acceptability of their proposals through direct experience with rejection or acceptance by a responder with whom they would not interact again, or: 2) a "full-information" treatment during which the participants were additionally informed about what kind of proposals their classmates made and whether these proposals were rejected or not.

The results demonstrated that children and adolescents, like adults, make higher proposals following a rejection and offer less in response to past acceptances. Furthermore, larger proposals made by other proposers led to larger own proposals in the next round, suggesting a role for conformity or social referencing in bargaining behavior in children and adolescents. However, unlike adults (Duffy & Feltovich, 1999), children and adolescents did not use information about whether their peers' proposals were accepted or rejected into their offers. Based on the notion that adult proposers learn from information about which offers from other proposers get rejected, it is likely that this capacity develops during adolescence, but this should be confirmed in future research in which these age groups are directly compared.

Learning to trust

A related question concerns how adolescents and adults learn to trust when they interact repeatedly with the same interaction partner. Van den Bos, van Dijk & Crone (2011) previously investigated this by giving participants in distinct phases of adolescent development (11-year-old early adolescents, 16-year-old mid-adolescents and 21-year-old late adolescents/young adults) the opportunity to play a repeated TG with three unknown peers who were in fact fictive players with preprogrammed behavior. The participants encountered a trustworthy, neutral and an untrustworthy interaction partner, who reciprocated in 80%, 50% and 20% of the trials respectively.

Results showed that participants in each age group learned to trust the trustworthy player the most and the untrustworthy player the least. However, the early adolescents showed no change in strategy during the game, whereas the 16-year olds and young adults started to trust the trustworthy player more and the untrustworthy player less. Furthermore, when confronted with betrayal, 11 year-olds mainly kept most of the money to themselves in the following trial instead of sharing again. Older participants, in contrast, more often tried to repair this breach of trust by trusting the player again, despite being defected on the previous trial.

Thus, an increasingly better understanding of the intentions of others and the consequences for others contribute to developmental changes in relation-specific trust.

Punishment and compensation

What could underlie these developmental increases in the tendency to repair ruptured cooperation? Van den Bos et al. (2011) hypothesized that the development of the ability control negative emotions associated with betrayal might account for the age-related decline in negative reactions to violated trust. To test this idea, participants were given the opportunity to punish the three different interaction partners in a costly punishment game (Fehr & Gächter, 2002). They could invest some of their earnings from the TG to decrease the outcomes of the other players. For each Euro paid by the participants 3 Euros were subtracted from the other player's profits. The results demonstrated that the participants punished the least trustworthy player the most and that the 11-year-olds invested more money to punish the untrustworthy player than the mid-adolescents and the adults. Developmental and individual differences in punishment behavior were associated with self-reported levels of anger toward the untrustworthy player. A mediation analysis demonstrated that older participants punished the untrustworthy player less and that this relation was mediated by decreases in anger.

Punishment after social exclusion

A similar developmental trend in punishing behavior was found in a study investigating the development of sensitivity to social exclusion and punishment of the peers who initiated the exclusion (Gunther Moor et al., 2012). Participants in this study were first included by two peers in a virtual-ball tossing game called Cyberball (Williams, Cheung, & Choi, 2000). In a second game of Cyberball, in which they were coupled with two novel players, they received the ball once at the start of the game, but they were excluded from the ball game in all of the following trials. A myriad of studies has shown that exclusion in Cyberball is as painful as real-life exclusion and leads to the threat of vital needs, such as the need for control and the need to belong as well as lowered mood (Williams, 2007). Following exclusion people selectively decrease prosocial behavior toward the people who excluded them (Hillebrandt, Sebastian, & Blakemore, 2011).

To investigate developmental differences in the punishment of the peers responsible for exclusion, early adolescents (age 10-12), mid-adolescents (age 14-16) and young adults (18-25) played two games of Cyberball followed by a DG in which they could allocate money to the people who included them (the includers), the people who excluded them (the excluders) and people they had not interacted with before (neutral others). Both adolescents and young adults offered an equal split of the stake to the includers and the neutral others, but selectively punished the excluders by offering them less than half of the stake. Interestingly, young adults behaved slightly more prosocial toward the excluders by more frequent allocations of 40% of the stake instead of allocating 20% like the early- and mid-adolescents (Gunther Moor, et al., 2012).

Could this developmental trend be the same in situations in which one is not the victim of a norm violation himself or herself? In a recent study, we investigated this question by giving participants the opportunity to witness an instance of social exclusion as opposed to being excluded themselves (Will, Crone, Van den Bos, & Güroğlu, 2012). In so doing, we were able to investigate developmental differences in both third-party punishment of the excluders and prosocial behavior toward a victim of social exclusion. Participants (age 9 to 22) were first included in a game of Cyberball by two includers and then observed the exclusion of a peer (i.e. the victim) by two excluders. Subsequently, they played two economic games in which they divided money between themselves and the includers, the excluders, and the victim: a standard DG and an Altruistic Punishment/Compensation Game (APCG) (Leliveld, van Dijk, & van Beest, 2012). In the APCG, participants can either do nothing or invest some money, which is then multiplied by 3 and either added to (compensation) or subtracted from (punishment) the other player's total.

The results from the DG showed that there was an age-related increase in money allocated to the victim from age 9 to age 22. Interestingly, instead of a linear decline in punishment behavior with age, we observed a quadratic age-related trend, such that 9 year olds did not punish the excluders (i.e. they allocated about 40-50% of the stake to both the includers and the victim as well as the excluders). Punishment severity then increased between age 11 and 16 and declined in young adulthood (age 22). Results from the APCG showed the same developmental trajectory, suggesting that the willingness to punish excluders is the same when it is costly to punish. Individual differences in an index of 'state affective perspective-taking' (an estimate of the victim's mood controlled for one's own mood following observed exclusion) predicted both more pronounced compensation of the victims and stronger punishment of the excluders. These results suggest that with increasing age, adolescents are willing to forfeit bigger rewards in order to punish excluders and to compensate victims of social exclusion and that taking the perspective of the victim enhances these decisions.

4.2 Neural correlates of repeated interactions

In the prior sections, we summarized studies showing that decisions about trust, reciprocity and fairness can be modulated by prior experiences with people we interact with. When comparing neural activation during repeated interactions, several brain regions respond in a similar way as when playing one shot games, but there is also additional involvement of regions which are important for learning. For example, Delgado and colleagues (2005) showed in an fMRI study how decisions in a TG and the neural circuitry underlying them can be modulated by the perceived moral character of the trustees. Participants played an iterated TG with three different interaction partners. Each of these players was described to the participants in short biographies that portrayed one player as morally good, one as neutral and one as morally bad. The results showed that despite the fact that each player reciprocated 50% of the time, participants still trusted the morally good partner more often than the other two partners toward the end of the experiment, suggesting that moral information about the people that we interact with can bypass rational taxation of their behavior. Delgado and colleagues (2005) showed that the caudate, a region previously associated with learning, differentiated between positive (being reciprocated) and negative feedback (being defected) during the TG (see also King-Casas et al., 2005). This response was attenuated when the participants interacted with the morally good and bad trustees. This indicates a mechanism for the way moral perceptions might bias our decision-making.

In order to investigate the neural correlates of interactions with personally familiar others, Güroğlu & Klapwijk (2012) recently conducted a study with young adults (age 20 years) from occupational universities. Sociometric nominations in their classrooms were obtained in order to gain information on the participants' positive (i.e., a friend) and negative (i.e., an antagonist) relationships. After the nominations, participants played multiple rounds of the TG as a trustor with three different interaction partners: two classmates (i.e., the friend and the antagonist) and a confederate who was a third anonymous peer they just met before the scan session. Preliminary findings showed that independent of interaction partner, there was activation in the insula during no-trust choices, and in the medial PFC during trust choices. Interestingly, interactions with the friend involved higher activation of the TPJ and the medial PFC than interactions with the antagonist, suggesting more mentalizing about other during interactions with friends (see also Denny, Kober, Wager, & Ochsner, 2012; Van Overwalle, 2009). Finally, the caudate was also more activated during positive feedback (i.e. reciprocate) following trust choices, as well as during negative feedback (i.e., defect) following no-trust choices, which again signifies the role of the caudate in feedback learning in a social context.

Taken together, the analysis of neural regions involved in repeated interactions again confirms the role of TPJ when there is a need for perspective taking, such as when thinking about consequences for friends. The repeated interactions illustrate that brain regions, which have previously been associated with non-social learning, such as the caudate, are also involved in social learning. This set of studies illustrates the potential use of real life interactions with known others as a tool for probing the mechanisms of how social interactions with specific interaction partners develop into relationships over time.

5. Implications and future directions

In this chapter, we summarized studies which together show that a basic concern for others is already present from a very young age. That is to say, when administering the DG, even young children already share a proportion of their goods with others, and in this sense they do not differ from adolescents and adults. However, when there is a need for strategic fairness or trust, young children do not yet adapt their social considerations to this changing context as well as adults. This ability emerges slowly during late childhood and continues to refine in adolescence, confirming that this is an important time for the fine-tuning of social considerations in the road to adulthood (Crone & Dahl, 2012).

In addition to the behavioral changes, the investigation of neural patterns revealed a consistent contribution of cortical areas which have previously been associated with cognitive control (DLPFC) and perspective-taking (TPJ) (Rilling & Sanfey, 2011). We showed in this chapter that across paradigms, these regions show a developmental increase in contribution to strategic and other-oriented motives in decision-making. Thus, it is likely that these processes and the underlying neural mechanisms explain a large proportion of variance in the development of fairness and trust considerations.

An interesting new direction in developmental neuroscience studies, which has not yet been well covered in the decision-making studies, is the elevated sensitivity to risks, rewards and losses in adolescence. There are several studies that have demonstrated that in simple reward processing paradigms (such as when winning money in a gambling task) the caudate/striatum is more active in adolescents compared to children and adults. This has been interpreted as an increased sensitivity to affective stimuli, possibly due to the large rise in gonadal hormones associated with puberty (Nelson et al. 2005). Interestingly, these elevated activations in the caudate/striatum are observed to a greater extent under social affective circumstances, for example adolescents take more risks in the presence of peers (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011).

Currently, it is not yet well understood how these variations in affective levels and associated brain activity in the caudate/striatum influence social decision-making behavior and activation in other brain regions such as the DLPFC and TPJ. However, it is likely that these neural responses in affective brain areas influence the way adolescents adapt flexibly to changing social contexts in daily life. One way to investigate this is by studying effects of communicated emotions of others on social decision-making (Lelieveld, Van Dijk, Van Beest, Steinel, & Van Kleef, 2011), by manipulating peer status (Muscatell et al., 2012), or by studying repeated interactions with personally familiar others (Güroğlu & Klapwijk, 2012). The overview of repeated interaction studies revealed that especially the caudate/striatum has an important role in social learning (Delgado et al., 2005), thus, the same region showing elevated responses to rewards in mid-adolescence. This leads to several compelling questions for future research, such as when and how adolescence is a period for developing other-oriented concern and prosocial behavior on the one hand and strategic play on the other hand.

Taken together, it is likely that changes in perspective-taking and cognitive control influence the way social decisions are made during adolescent development. However, at the same time adolescents navigate this complex phase in life well. For example, new friendships are formed and there is a rapid adaptation to changing social cultures. One underlying mechanism may be this heightened sensitivity to affective cues, which may help them to adapt quickly and flexibly to changing social demands. Future studies should examine how sensitivity to reward and punishment changes during adolescence and whether there are unique opportunities in adolescent development for attaining status and adaptively exploring their social world. Investigating the role of reward sensitivity in the social decision-making processes in the peer context might be the challenge of studies in the near future.

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Figure 1: Brain regions involved in social-decision making (see text for explanation). PFC= prefrontal cortex. TPJ= temporal parietal junction. OFC= orbitofrontal cortex. DLPFC=dorsolateral prefrontal cortex. VLPFC=ventrolateral prefrontal cortex.

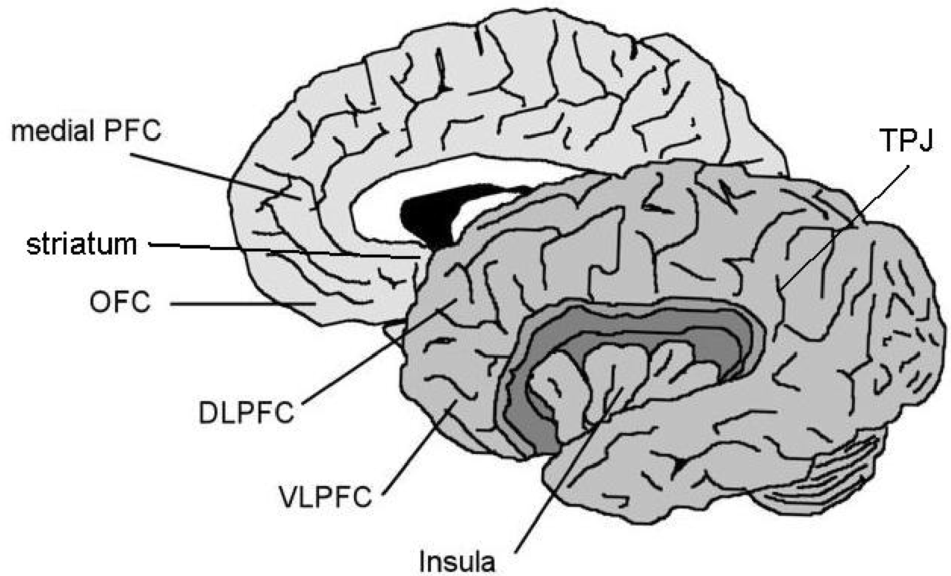
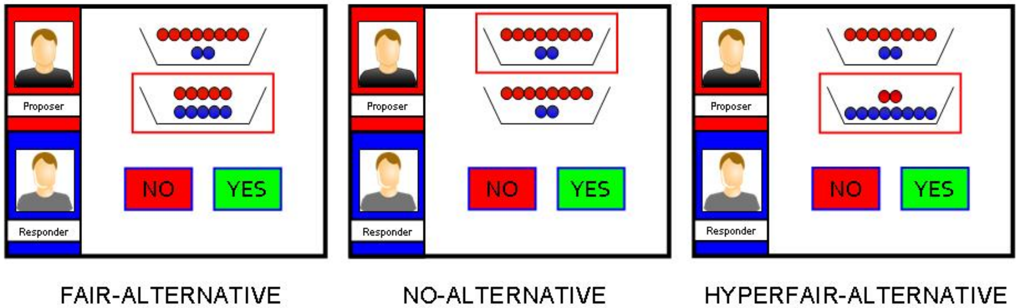
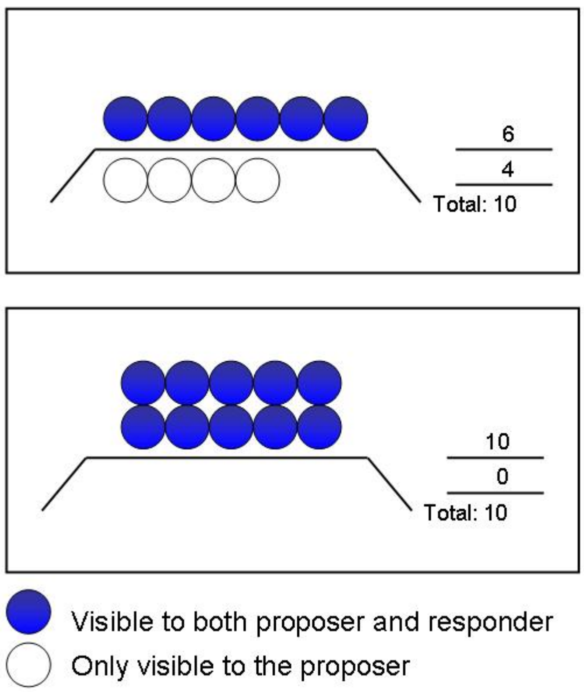


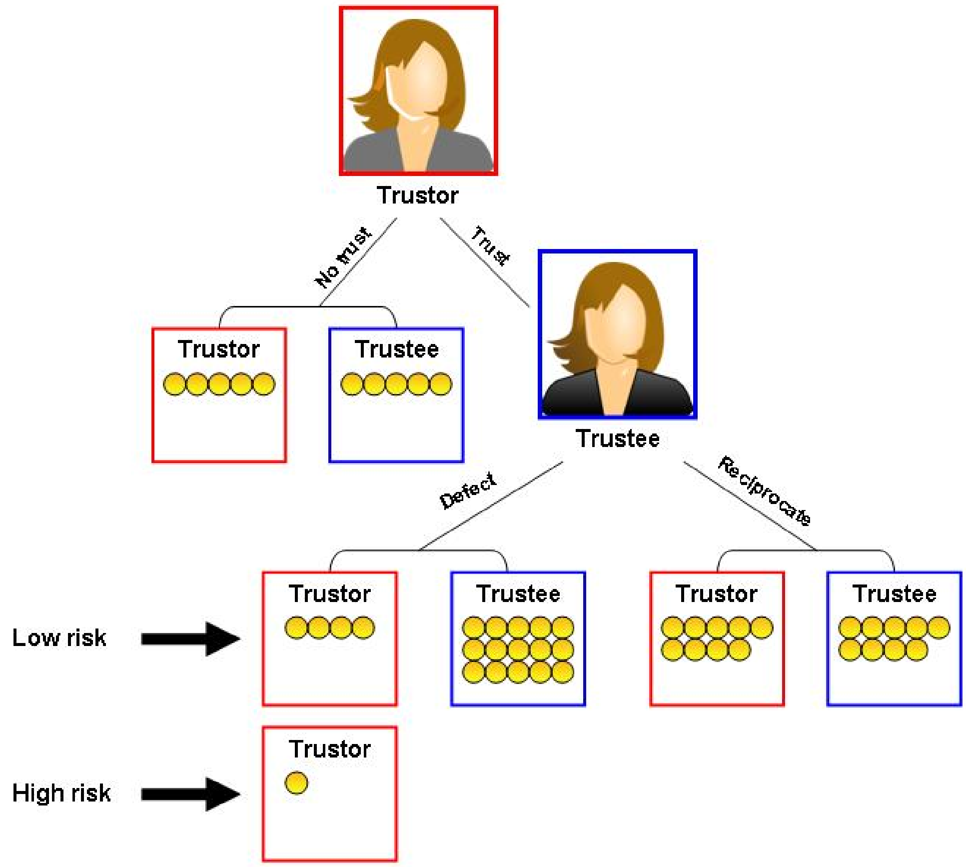
Figure 2: Schematic display of one trial of the mini Ultimatum Game (A), the hidden Ultimatum Game (B), and the Trust Game with risk manipulation (C).



2A



2B


Trustor
No trust
Trust
Trustor
Trustee
Trustee
Defect
Reciprocate
Low risk
Trustor
Trustee
Trustor
Trustee
High risk
Trustor

2C