The handle http://hdl.handle.net/1887/45006 holds various files of this Leiden University dissertation.

**Author**: Hoorn, J. van  
**Title**: Hanging out with the right crowd: behavioral and neuroimaging studies of peer influence on decision-making in adolescence  
**Issue Date**: 2017-01-12
Chapter 6:

Summary and general discussion

1. Summary

So, were my parents right when they warned me about negative peer influence as a teenager? The answer that many parents, including mine, have often heard is “Yes, but…”

The main goal of this thesis was to investigate peer influence on decision-making in adolescence. Taken together, the studies in this thesis provide a scientific basis to refine the negative connotations of peer influence. The effects of peers on risk-taking behavior are present, but are dependent on context. Adolescents take into account both social norms from peer feedback and the uncertainty associated with outcomes in risky decisions (Chapter 2). Moreover, I delved into the adaptive side of peer influence, which to date has received little attention in research. Peers can both increase and decrease prosocial behavior in typically developing (TD) adolescents and those with autism spectrum disorders (ASD), illustrating that peer influence can also lead to positive psychosocial outcomes (Chapter 3 and Chapter 5). Finally, I examined the underlying neural processes and showed that prosocial peer influence is underlined by a network of social brain regions in the adolescent brain that is involved in thinking about the self and others (Chapter 4). A summary of each of these chapters will be described below, followed by an overall discussion, future directions, implications and conclusions.

Peer influence on risk-taking behavior

The first empirical chapter (Chapter 2) describes the effects of peer feedback on risk-taking behavior and the validation of a novel experimental paradigm, the guess gambling game (GGG). Peer influence plays a central role in the increase of risk-taking behavior during adolescence (Albert et al., 2013; Brechwald & Prinstein, 2011). However, at present the processes underlying peer influence on risk-taking are not fully understood. In this study I examined how peer advice influenced risk-taking behavior in adolescents between fifteen and seventeen years of age. I implemented the GGG to measure risk-taking behavior in the peer context. In this card-guessing game, participants were presented with two playing cards from a deck of hearts ranging between one (Ace) and nine. After the first card was presented face up participants were asked to guess whether the next card would be higher or lower (guess). In addition, participants could place a variable bet with poker chips on whether they guessed correctly (gamble). This task provided the possibility to disentangle peer effects on rational guesses and gambling (i.e., risk-taking behavior); and to vary the uncertainty of the outcome, with card 5 being most uncertain, whereas card 1 and 9 had entirely certain outcomes.
The GGG was played alone in one condition and with manipulated advice from online peers on how many chips to bet (low bet, medium bet or high bet advice) in the other. As such, the different advice types signaled social norms about how many tokens to bet. Findings indicated that guessing patterns were similar with and without peers present. This result suggests that the presence of peers does not change the ability to reason about card probabilities (Reyna & Farley, 2006; Van Duijvenvoorde & Crone, 2013; Van Leijenhorst et al., 2010). However, in line with previous work gambling behavior increased in the presence of peers (e.g. Gardner & Steinberg, 2005; Smith et al., 2014). Importantly, effects of peer advice on gambling behavior were differentiated depending on the uncertainty associated with gambles as well as the social norms signaled by peer advice. Peer feedback was most influential in such uncertain situations. In conclusion, during gambling decisions adolescents seem to make active meaning of the context, integrating information from peer feedback and outcome (un)certainty. These findings resonate with the economic decision-making literature that suggests that adolescents have the cognitive capacity to make prudent decisions, but tend to pursue more risky courses of action in a ‘hot’ context (for example with peers) (Figner et al., 2009; Shulman et al., 2016). This differentiated effect of peer feedback demonstrates the value of a social norms approach in examining the process underlying peer effects. Subsequently, I applied this approach to a new paradigm that measures prosocial decision-making during adolescence.

Peer influence on prosocial behavior and its neural correlates

In Chapter 3 I examine the adaptive side of peer influence as a process that may create opportunities for prosocial development during adolescence (Allen & Antonishak, 2008; Crone & Dahl, 2012). Some evidence from non-experimental studies suggested links between peer influence and prosocial outcomes in dyads and larger peer groups (e.g. Barry & Wentzel, 2006; Berger & Rodkin, 2011), but such outcomes have not been studied before with an experimental task. In this study I validated a novel experimental paradigm called the peers public goods game (PGG) in a large sample of adolescents twelve to sixteen years of age. In this social dilemma, participants made decisions in an anonymous four-person group about the allocation of tokens between themselves and the group (Harbaugh & Krause, 2000; Ledyard, 1995). Participants were informed that all tokens donated to the group would be doubled and split over the four group members. They were also told that they could keep the tokens that they did not donate. As such, participants had to balance self-interest and concern for the group in making their prosocial decisions (Ledyard, 1995). In this task on-the-spot prosocial behavior was quantified as the number of tokens donated to the group.
To test the hypothesis that peers influence prosocial decision-making, adolescents played the PGG alone and with manipulated peer feedback from a group of spectators for a number of decisions. Results indicated that changes in prosocial behavior were dependent on the social norms of the peer group. Prosocial behavior increased after prosocial peer feedback (i.e., likes for large donations to the group) and decreased after antisocial peer feedback (i.e., likes for not donating). There were no changes in prosocial behavior when participants played with peers only present (i.e., peers observing behavior). These findings highlight the view that peer influence creates not only vulnerabilities, but also opportunities for prosocial development and social adjustment learning. Next, I examined what happens in the adolescent brain during prosocial decision-making with peers present.

Chapter 4 describes the results of an fMRI study in which I used a modified version of the PGG task (Chapter 3) to examine the neural correlates of prosocial peer influence on prosocial behavior during adolescence (ages 12-16 years). Previous neuroimaging work has shown that risk-taking in the presence of peer results in enhanced ventral striatum (VS) activity in adolescents, but not in (young) adults (Chein et al., 2011). Yet, the neural processes underlying prosocial peer influence effects are not well understood. Previous research in adults suggests a role for medial prefrontal cortex (mPFC) and VS in the context of peer evaluation. The mPFC is implicated in mentalizing (thinking about self and others), social cognitive processes and social influence (Izuma, Saito, & Sadato, 2010b; Falk et al., 2014; Welborn et al., 2016).

In the MRI scanner, participants played the PGG alone, with spectators observing decisions, and with prosocial feedback. This time, the online spectator groups of same age peers were in fact youth actors who participants had met before the start of the study. Behavioral results showed that prosocial behavior increased in the presence of peers, and even more when participants received prosocial feedback from peers. On the neural level, peer presence during donation choices resulted in enhanced activity in several social brain regions including dorsal mPFC, TPJ, precuneus, and STS. These findings highlight the role of mentalizing regions in peer influence and are consistent with research relating to the effect of prosocial behavior towards the family (Telzer, Masten, Berkman, Lieberman, & Fuligni, 2011) and public goods donations in adulthood (Bault, Pelloux, Fahrenfort, Ridderinkhof, & Van Winden, 2015). Peer presence effects were larger in dmPFC and STS for early adolescents (12-13 years olds) than for mid-adolescents (15-16 years olds), suggesting that younger adolescents may be more susceptible to their social context. These findings shed light on the role of peers in fostering prosocial development throughout adolescence. With this background in typical development, I turn to Chapter 5 that examines peer influence effects in adolescents with autism.
Peer influence on prosocial behavior in autism
Like typically developing adolescents, those with autism spectrum disorders (ASD) show a social reorientation towards peers when they transition from childhood to adolescence (McGovern & Sigman, 2004; Carter et al., 2014). However, adolescents with ASD often struggle to understand social situations (Tantam, 2003). Given the difficulties in social interaction and interaction as well as theorized diminished motivation, I hypothesized that adolescents with ASD would show attenuated sensitivity to the peer context (Yafai, Verrier, & Reidy, 2014). In the study described in Chapter 5, I examined whether adolescents with and without autism were influenced by peer feedback on prosocial behavior. In addition, I investigated whether autism symptoms and social interest were related to individual differences in feedback sensitivity. Hence, the PGG included a prosocial and antisocial feedback condition (slightly adapted from Chapter 3 and Chapter 4) and was applied in a large sample of adolescent boys with and without ASD in the ages of eleven to seventeen years.

Findings showed that ASD and TD adolescents were sensitive to peer feedback concerning prosocial behavior. Replicating the earlier behavioral findings, participants donated more tokens when peers endorsed prosocial behavior. There was a decrease in prosocial behavior when peers liked selfish behavior. Interestingly, I discovered that adolescents with ASD were also sensitive to peer feedback on prosocial decisions. Despite atypical social development, peer feedback may create an opportunity for social adjustment learning in ASD adolescents. Within the total sample those with more autism symptoms and more social interest were less sensitive to antisocial peer influence. Taken together, autism symptoms and social interest may constitute a protective factor for sensitivity to antisocial peer feedback. These findings provide a building block for interventions and suggest that a peer component may affect change in prosocial behaviors in adolescents with ASD.

2. General discussion

Taken together, the studies presented in this thesis show that peer influence in adolescence can be characterized as a socialization process that leads to health-compromising risky behaviors (i.e., increased gambling), but also to positive psychosocial outcomes (i.e., increased prosocial behavior). In this section, I highlight several discussion points that result from the work in this thesis. First, we need to verify whether the current findings converge within the broader domain of prosocial behavior. Next, it is important in peer influence research to consider the differences between peer presence and peer feedback, as well as the salience of the source of influence because these factors influence peer effects.
Then I discuss the neural correlates of prosocial peer influence and the implications for neurodevelopmental models. Finally, I propose that we need to investigate how unique the findings in the final chapter are to autism spectrum disorders.

The studies in this thesis show that peers influence prosocial decisions of adolescents – for better and for worse. This is consistent with views of adolescence as a period of flexibility and adaptation, and being specifically attuned to the social context (Blakemore & Mills, 2014; Casey, 2015; Crone & Dahl, 2012). Yet prosocial behavior is a multidimensional construct that encompasses various types of behaviors, of which one specific type was assessed in this thesis: cooperation to benefit one’s group (Padilla-Walker & Carlo, 2014; Wentzel, 2014). It is important to examine how the current findings map on other types of prosocial behaviors. A recent experimental study found that peers also positively affected intentions to volunteer in adolescence (Choukas-Bradley, Giletta, Cohen, & Prinstein, 2015), providing initial evidence for convergence of experimental peer effects within the domain of prosocial behavior.

Across the current studies, peer observation without feedback (peer presence) increased prosocial behavior when participants met adolescent actors as peers before the start of the study (Chapter 4), but showed no effect when these peers were anonymous online others (Chapter 3 and Chapter 5). This disparity suggests that the effects of peer observation may be dependent on the salience of the peers who evaluate these decisions. Peer influence and friendship theories suggest that peer effects are stronger for friends (see Berndt, 2002; Hartup, 2005), although such comparisons have not been directly tested to date. Comparing friends or known peers to unknown peers in an experimental design raises multiple issues concerning background knowledge, including whether social norms and their perception in daily life match with manipulated social norms. That is, would friends approve or encourage prosocial behavior in daily life (i.e., injunctive norms) or does the class engage in such behaviors (i.e., descriptive norms) (McDonald & Crandall, 2015)? Adding a questionnaire that taps into positive and negative perceived peer norms, such as the recently developed Peer Group Norm questionnaire, would be an important step towards addressing this issue (Marshall-Denton, Véronneau, & Dishion, 2016). Taken together, to gain a deeper understanding of the complex peer influence process, it is important to consider what it is about those peers and which processes lead to subsequent changes in behavior. One way of examining these processes is to investigate what happens in the brain during decision-making.

During prosocial decision-making peers evoked activation in the social brain network, including cortical social brain areas (dorsomedial PFC and TPJ) (Chapter 4). This suggests
that making prosocial decisions with peers present activates social-cognitive processes (e.g. Welborn et al., 2016; Somerville et al., 2013). However, there was no evidence for reward-related activity during prosocial decision-making with peers present. Previous work reported that peer influence during risk-taking behavior elicits heightened activation in subcortical reward-processing areas, mainly ventral striatum (VS) (Chein et al., 2011, Smith et al., 2015). That finding has been interpreted as evidence that peer presence increases the motivational salience of rewards, or in other words, that peers make risky behavior more rewarding. The PGG task was optimized to examine peer effects on prosocial behavior and did not have an outcome phase, because participants did not learn about the contributions of the other players. As such, the anticipation of reward was also dependent on decisions of the other group members and may not have provided a steady learning signal for the VS (see meta-analysis Silverman, Jedd, & Luciana, 2015).

In trying to explain these neural findings, I propose that perhaps peer influence heightens activity in task-relevant brain areas, contingent on the type of behavior. Heightened activity may be reflected as enhanced reward-related processing in VS during risk-taking behavior, and in social brain areas such as mPFC and TPJ in the context of prosocial behavior. Currently, it is unclear how the motivational circuit and social brain network interact to shape peer influence processes. The recent refinement of the dual systems model (Shulman et al., 2016) acknowledges that social context moderates developmental effects in decision-making, but does not consider how this expands the neural circuitry involved (Pfeifer & Allen, 2016). The current findings speak to this debate and highlight that it is crucial to study the affective and social brain networks and their interactions with cognitive control networks collectively rather than separately. Doing so may be possible with a task that draws upon both affective and social processes to begin with (e.g., gambling for a friend; Braams, Peters, Peper, Güroğlu, & Crone, 2014), and adding a peer influence condition. Using different analyses, such as functional connectivity, may also shed light on how the social brain network interacts with affective and control neural networks during decision-making with peers present (see e.g. Somerville et al., 2013).

Finally, both typically developing (TD) adolescents and those with autism spectrum disorders (ASD) are influenced by peer feedback. Hence, it seems that the basic process of learning from peers is present in ASD adolescents despite atypical social development. It is crucial to investigate whether these findings are specific to ASD and how they relate to other clinical groups characterized by atypical social development. For example, adolescents with conduct disorder may be less influenced by peer feedback, whereas those with social
anxiety disorder may be especially attuned to peer feedback (Haller, Cohen Kadosh, Scerif, & Lau, 2015; Klapwijk et al., 2016). With an increased understanding of the interactions in the peer context in typical and atypical social development, we may be able to help adolescents navigate this time of their lives as an opportunity rather than vulnerability for development.

3. Future directions

There are many other outstanding questions for future research. For instance, to what extent do peers affect cognitive control during adolescence? Initial evidence shows that adolescent – but not adult – performance on a cognitive relational reasoning task is affected by an audience (Wolf, Bazargani, Kilford, Dumontheil, & Blakemore, 2015). A recent follow-up neuroimaging study used a similar relational reasoning paradigm with somewhat different audiences and showed that relational reasoning performance decreased in both adolescents and adults, while activity in the fronto-parietal network increased in the presence of a peer for adolescents only (Dumontheil, Wolf, & Blakemore, 2016). Taking a slightly different approach, one recent study related brain activation in control systems (inferior frontal gyrus and basal ganglia) during a go-no-go task to simulated driving behavior with a peer one week later (Cascio et al., 2015). Activation in control systems was predictive for safer driving when a cautious peer confederate was present; but not with a risk-encouraging peer confederate. This context-dependent activation implicates that neural resources are used differently depending on characteristics of the source of influence (Cascio, Scholz & Falk, 2015).

Moreover, most studies, including those in this thesis, have not compared peer influence to other sources of influence, such as parents. In the neutral domain, peer and parental influence seem to rely on the same neural basis (Welborn et al., 2016). These brain areas include mentalizing areas (mPFC, TPJ), reward-related areas (vmPFC) and areas associated with self-control (vIPFC). The neural findings align with developmental comparisons in the domain of social influence on risk-taking, which suggest that peers are more influential than adults only in early adolescence (12-14 year-olds) (Knoll et al., 2015). Indeed, in the prosocial influence task early adolescents relative to mid-adolescents showed more differentiation in dmPFC activation during decision-making with peer feedback than alone. These neural findings suggest that early adolescents are more sensitive to the peer context in the domain of prosocial behavior. More research is needed to replicate these findings, further clarify neural and behavioral developmental patterns and compare sources of influence in various
contexts (risk-taking, prosocial, neutral) in order to draw conclusions about the specificity of the current findings.

Besides the features of the source of influence on which this thesis was mostly focused, characteristics of the target of influence may also magnify or mitigate effects of peer influence (Brechwald & Prinstein, 2011). Several factors have been of interest in research, including age and gender, but also personality traits such as responsivity to (social) reward (Gardner & Steinberg, 2005; Reniers, Beavan, Keogan, Furneaux, Mayhew, & Wood, 2016; Stautz & Cooper, 2014; Steinberg & Monahan, 2007). Developmental patterns in sensitivity to peer influence seem to differ depending on the methods employed and domain of behavior studied (see e.g. Berndt, 1979). We are only beginning to understand how the interaction between individual traits and characteristics of the social environment embedded in various domains of behavior shape the complex process of peer influence. Future studies investigating individual differences in sensitivity to peer influence would benefit from comprehensive samples covering childhood to far in adulthood, cross-sectional designs using more specific definitions of adolescence, and longitudinal designs to examine change within individuals over time (also see Van Duijvenvoorde, Peters, Braams, & Crone, in press).

4. Practical implications

This research provides a scientific basis to reshape predominantly negative connotations associated with peer influence in society. Peer influence effects on risk-taking behavior represent one side of this phenomenon. Understanding the processes underlying peer influence on risk-taking may provide targets for intervention. Doing so is crucial in order to help adolescents navigate this developmental period successfully and bring down the 300% rise in morbidity and mortality due to preventable risk-taking behaviors (CDC, 2013). A review of previous interventions reports that the use of the social norms approach to decrease drinking behavior in college students yielded mixed results (Prentice, 2008). These campaigns have mainly focused on descriptive norms (for example, introducing a true norm about how many drinks are “normal”) and have barely touched upon injunctive norms (e.g., peers endorsing restraint in drinking behavior). The findings in this thesis suggest that injunctive norms may be a good target to induce a positive change in drinking behavior.

The other side of peer influence can be described as an opportunity for prosocial development and social adjustment learning. The findings are also a promising basis for interventions to promote prosocial behaviors. One example is the Good Behavior Game designed for primary
schools in which disruptive and non-disruptive students work together in small teams (Van Lier, Huizink, & Vuijk, 2011). Peer influence and social norms may contribute to the effects of this intervention, because the entire team gets a reward for endorsing positive and prosocial classroom behavior. So far, programs for adolescents have received less attention (but see CEPIDEA; Caprara, Luengo Kanacri, Zuffianò, Gerbino, & Pastorelli, 2015). A recent meta-analysis about school-based interventions does suggest that early adolescents are more sensitive than children to interventions focused on positive peer relations, because of the increased salience of fitting in and having good relationships with peers (January, Casey, & Paulson, 2011). This meta-analysis is in line with the findings in this thesis and suggests that adolescence is a period during which an intervention to promote prosocial behaviors with a peer component may be effective.

Finally, this research also has clinical implications. Chapter 5 showed that boys with and without autism spectrum disorders (ASD) are influenced by feedback from peers. This attunement to the peer environment opens doors for training social skills and prosocial behavior. Given the tremendous heterogeneity in ASD, it is yet unclear which interventions work for whom (Ledford et al., 2016). The findings suggest that peer feedback may be an effective mechanism to alter prosocial behaviors in high-functioning boys with ASD. Naturally, findings from a controlled experimental environment do not directly map on complex real-life social situations and we need to identify individual and environmental factors that magnify or mitigate sensitivity to peer feedback. Collaborations between experimental and intervention research could be fruitful in determining which active ingredients are necessary for interventions in TD and ASD adolescents.

5. Conclusions

In conclusion, this thesis provides a comprehensive overview of peer influence effects on decision-making. Peer influence can be characterized as a socialization process that leads to health-risk behaviors on the one hand, and positive psychosocial outcomes on the other hand. The neural findings further inform the debate about including social context in neurodevelopmental models of decision-making in adolescence, and show that affective and control networks should be studied collectively with social brain networks. By further researching the effects of peer influence, we may be able to assist adolescents in navigating a complex social phase of their lives. Eventually, these results can contribute to interventions aimed at decreasing risk-taking and promoting prosocial behavior in adolescence, with possibly long lasting effects into adulthood.