Psychologie
Faculteit der Sociale Wetenschappen

Universiteit Leiden

Social status and sensitivity to risk-taking: A cross-sectional ERP/EEG study in adolescents

Karine van Schie

Master Thesis Child and Adolescent Psychology
Faculty of Social and Behavioral Sciences – Leiden University
August 2017
Student number: 1421271
Supervisor: Dr. C.K.K. Zanolie
Second reader:
Date of approval:

Signature supervisor:
Signature second reader:

Table of Contents

Abstract

During adolescence, the period between childhood and adulthood, the increase of risk-taking behavior as well as social re-orientation plays a major role. Risky behavior among adolescents is often investigated through reward-processing (gambling) tasks in MRI, fMRI and ERP/EEG (event-related potential/electroencephalography) research. This study examined differences in the feedback-related negativity (FRN), also known as the medial-frontal negativity (MFN), at FCz in three different age groups within adolescence, using a simple gambling task involving unpredictable gains and losses of low and high numbers of coins. Also the influence of social status was examined. The results of the behavioral data showed a considerable trend toward significance of social status on high choices. High status participants selected more often high numbers of coins (instead of low numbers of coins) than low status participants. Analysis of the electrophysiological data showed larger (more negative) FRN's after losses than after gains and larger FRN's for low numbers of coins than for high numbers of coins. In addition, there was an interaction effect between the type of feedback and the social status of the participants. Participants with a low status had larger FRN's after losses than participants with a high status. For participants with a high status was the amplitude of the FRN slightly larger after gains than for participants with a low status. There was a significant effect of age group, showing that the age group 10-13 years had significantly larger FRN amplitudes than the age group 14-17 years, regardless the type of feedback or the number of coins. Because there was no significant interaction effect with age group, it is not possible to draw any conclusions about the differences between the age groups. Taken together, most of the results are consistent with previous studies and are discussed in the context of feedback processing and (sensitivity to) risk-taking during adolescence.

Introduction

Adolescence can be described as a stage of development between childhood and adulthood (Feldman, 2009). This phase begins at the onset of the pubertal maturation (9-12 years) and starts usually 1-2 years earlier in girls than in boys. During this period various physical, cognitive and social changes take place (Crone & Dahl, 2012; Feldman, 2009). During the first phase of adolescence (also known as early-to-mid adolescence), the increase in the secretion of pubertal hormones is responsible for many changes in physical appearance (Braams, Leijenhorst, & Crone, 2014). During the second phase of adolescence (also defined as mid-to-late adolescence), social roles and responsibilities are adjusted (Crone & Dahl, 2012). This phase begins from approximately 15-16 years and ends just after teenage years. Exploration, sensation-seeking and eventually setting long-term goals and ambitions are common within this period (Braams et al., 2014).

During adolescence the brain is developing rapidly, both structurally and functionally. There are actually two important processes that take centre stage. On the one hand, the increase of risk-taking behavior by exploration and sensation-seeking plays a major role. On the other hand, social re-orientation has great importance during adolescence. Social re-orientation is the process of forming new peer relations and becoming less dependent from parents. Adolescents explore their own social environment in which they distance themselves from the safe parent environment (Peper, Koolschijn, & Crone, 2013).

There are many factors that influence risk-taking behavior. According to Steinberg (2008), maturational timing, temperamental predispositions, and opportunities to engage in risk-taking could stimulate the transition from sensation-seeking into risky behavior. To understand the risky behavior of adolescents it is important to consider biological causes and brain development during this period of development. This is a dynamic and complex process with a continuous progress into adulthood (Koolschijn & Crone, 2013; Peper et al., 2013).
A part of the risk-taking behavior during adolescence can be explained by changes in neural systems of motivation and emotion (Dahl, 2004). A neurobiological model shows the underlying patterns of adolescent brain changes and development. A connection between the prefrontal cortex, responsible for mediating cognitive and impulse control, and subcortical limbic regions, important for emotional and action-regulating behavior, is reflected in this model, see Figure 1 (Somerville, Jones, & Casey, 2010, p. 126). Both systems are still

developing, but there is an imbalance created between emotion systems and cognitive control systems. According to this model, the subcortical limbic areas develop earlier than the prefrontal cortex. The nonlinearity of these systems makes sure that the subcortical limbic regions are relative mature, making emotional and action-regulating behavior stronger than control signaling, which is thought to be reflected in increasing risky behavior (Somerville et al., 2010; Casey, Getz, & Galvan, 2008).

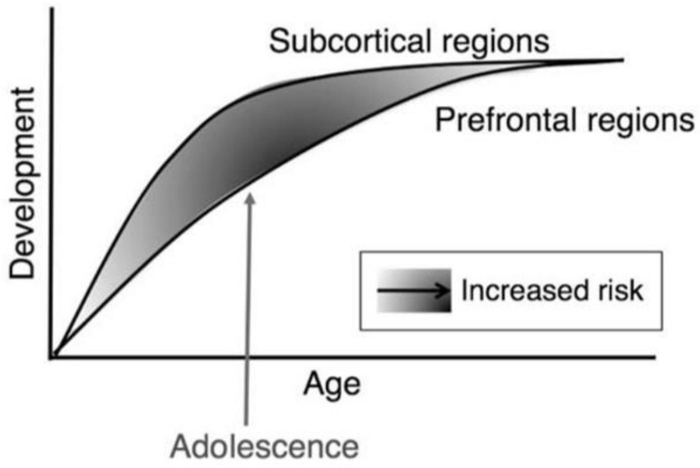

Figure 1. Model for enhanced affective and incentive-based behavior in adolescence. Early maturation of subcortical regions such as the amygdala and ventral striatum (top line), combined with late maturation of prefrontal cortical regions (bottom line), predicts a nonlinear enhancement in affectively-driven behavior during adolescence. Reprinted from "A time of change: Behavioral and neural correlates of adolescent sensitivity to appetitive and aversive environmental cues," by L.H. Somerville, R.M. Jones, and B.J. Casey, 2010, *Brain and Cognition*, *72*, p. 126,

Although the imbalance between emotion systems and cognitive control systems, risk-taking behavior is also being studied in other MRI, fMRI and ERP/EEG (event-related potential/electroencephalography) research. A functional MRI study of participants between 10 and 25 years old shows that activation in the ventral striatum and medial prefrontal cortex seems to be related to risky decisions (Duijvenvoorde et al., 2014). According to Feldman (2009), the prefrontal cortex develops especially during adolescence and could explain risk-taking behavior. This part of the brain regulates thinking and impulse control. The fact that this area is not yet fully grown during this period plays an important role. The weaker responses in this region responsible for inhibition compared to adults may be a possible explanation for the impulsive behavior (Kalat, 2013; Feldman, 2009). A recent study by Braams, Peters, Peper, Güroğlu, and Crone (2014) examined participants between 8 and 25 years old using a reward-processing (gambling) task where participants could win or lose money for themselves, friends or disliked peers. The fMRI results demonstrate more neural activation in the bilateral ventral striatum for self than for the friend and the antagonist. An age related effect in activity in the ventral striatum for themselves showed a peak around age 15. The ventral striatum showed greater activation after winning compared to losing and this activity is associated with age during adolescence, showing a peak around age 16 (Braams et al., 2014).

Reward processing is also often explored through event-related potential (ERP) research. In a gambling task Gehring and Willoughby (2002) showed a negative-polarity ERP, the medial-frontal negativity (MFN), also known as the feedback-related negativity (FRN), to be more negative after losing compared to after winning (Gehring & Willoughby, 2002). The FRN peaks at about 250 ms after feedback onset (Zottoli & Grose-Fifer, 2012; Hämmerer, Li, Müller, & Linenberger, 2010).
A study of factors that influence the FRN among 16- to 17- year-old adolescents and 18- to 29-year-old adults showed genuinely that the FRN was larger (more negative) in response to loss feedback compared to win feedback, but no age differences were found (Santesso, Dzyundzyak, & Segalowitz, 2011). A study by Zottoli and Grose-Fifer (2012) among adolescent males between 14 and 17 years old and adult males between 22 and 26 years old found similar results. However, the amplitude of the FRN was larger in adolescents than in adults (Zottoli & Grose-Fifer, 2012). Another study of them also showed that the FRN was larger for low than for high outcomes (Grose-Fifer, Migliaccio & Zottoli, 2014). Finally, there are differences in development been found with respect to the FRN. “The amplitude of the FRN after losses or gains decreased with increasing age in a monotonic fashion” (Hämmerer et al., 2010, p. 587). This study among four age groups showed a larger FRN in reaction to positive and negative feedback in children (9-11 years), followed successively by adolescents (13-14 years), younger adults (20-30 years) and older adults (65-75 years) (Hämmerer et al., 2010).

Besides the development of the brain and neural activity during risk tasks, there is also a second process that takes centre stage during adolescence and influences the increase of risky behavior, namely changes in emotional and social behavior, which arise from advances in self-regulating abilities. The formation of self-identity in combination with the focus on social relationships is an important process (Crone & Güroğlu, 2013). Radical changes such as changing school ensure that adolescents meet new people and build social relationships with peers. In other words, “school is an important venue for peer relationships for many adolescents because school is where most young people meet others, form friendships, and become a part of groups” (Woodhouse, Dykas, & Cassidy, 2011, p. 274). Besides school adolescents also create friendships with peers from their neighborhood, part-time jobs, hobby’s or sports (Rubin, Fredstrom, & Bowker, 2008). Social re-orientation ensures that relationships with friends and peers become stronger and the dependence of parents becomes weaker (Braams et al., 2014). Within this social orientation process social status is an important aspect in addressing behavior in general and peer groups in particular (Boksem, Kostermans, Milivojevic, & De Cremer, 2012). The sense of belonging to a group and having a high social status has positive influences on behavior (Boksem et al., 2012) and physical wellbeing (Begen & Turner-Cobb, 2011). Also, friendships are protective and positive factors in the lives of children and adolescents (Rubin et al., 2008). However, certain characteristics of friends or friendships may also have a negative impact on outcomes of adolescents (Knack, Jacquot, Jensen-Campbell, & Malcolm, 2013). For instance, popularity, which is an index of social regard and visibility, and is often seen as a dimension of social status, affects risk-taking behavior (Badaly & Schwartz, 2012). Allen, Porter, McFarland, Marsh, & McElhaney (2005) found that popular adolescents were more likely to engage in risky behaviors such as alcohol and substance use and minor delinquent behavior compared to less popular adolescents. Thus, they seem vulnerable to being socialized into the increasing levels of risk-taking behavior (Allen et al., 2005).

Probably different aspects could clarify the sensitivity to risk-taking behavior during adolescence. Brain development, social status, and the phase of adolescence could be important in this relationship. Although many different studies focused on sensation-seeking and risk-taking behavior during adolescence and various approaches for this behavior have been studied, few studies have examined the influence of (manipulated) social status on risk-taking behavior and the processing of feedback (gains versus losses) among the different phases of the adolescence.

It is expected that there is a link between the developmental progress of the subcortical regions and the prefrontal regions and risk-taking behavior. According to Steinberg (2008), risk-taking behavior is common in 18- to 21-year-olds (late adolescence). However, based on the neurological model of the imbalance between emotion systems and cognitive control systems it can be expected that this behavior is more common in the mid adolescence

(Somerville et al., 2010; Casey et al., 2008). So in which age group is the risk-taking behavior actually higher? And is increased risk-taking influenced by social status? It is expected that the social status affects the risk-taking behavior of adolescents. Adolescents with a high status will take more risks than adolescents with a low status. The link between risky behavior and social status is clearly evident in the study of Allen and his colleagues. It was shown that popular (high status) adolescents seem more sensitive to higher levels of risky decisions (Allen et al., 2005). A next major question relates to the neural activity in the processing of gains or losses at the time of feedback (FRN). Are the FRN amplitudes larger in winning or in losing? And is the FRN actually larger for high or low numbers of coins? Based on previous studies it is expected that FRN amplitudes are larger in losing instead of winning and larger for low than for high outcomes (Grose-Fifer et al., 2014; Zotolli & Grose-Fifer, 2012; Santesso et al., 2011; Hämmerer et al., 2010; Yeung & Sanfey, 2004; Gehring & Willoughby, 2002). Furthermore, it is interesting to see whether social status affects the FRN of adolescents. It is expected that adolescents with a low status will be more sensitive to losses than adolescents with a high status (Boksem et al., 2012), which can be expressed in a larger FRN. Finally, the last question is related to the results of the FRN amplitudes in relation to the different phases in adolescence. In which age group is the FRN larger or just smaller? Does the amplitude of the FRN after gains and losses actually decrease with increasing age, as revealed in the study of Hämmerer and her colleagues (2010)? And is there a difference for negative feedback (loss) compared to positive feedback (gain) within the three age groups? And what about a low or high status? Based on the literature, it is expected that there is a greater difference for early-adolescents with a low status in response to negative feedback.

The aim of this present cross-sectional ERP/EEG study is to investigate developmental differences in the FRN in normally developing adolescents across three age groups. Through a gambling task the neural activity in the processing of gains or losses at the time of feedback (FRN) will be determined. Also the degree of risky choices and the influence of (manipulated) social status are examined.

Methods

Participants

The original study sample consisted of Dutch participants, divided over three age groups, namely 10-13 year-olds (17 females and 19 males, mean age = 11.64 years ± 1.13), 14-17 year-olds (19 females and 13 males, mean age = 14.78 years ± 0.83) and 18-22 year-olds (21 females and 4 males, mean age = 19.12 years ± 1.27). Two participants had to be excluded due to incomplete data. Among the total sample (n = 93), 30 participants were excluded for the EEG analyses due to recording or technical problems, or because they did not commit enough gain or loss trials. Participants were recruited from primary, secondary schools and vocational university in the surroundings of Leiden and Amsterdam. None of the participants reported medical or mental problems on the telephone screening. All participants, and in case of participants younger than 16 years, the parents signed an informed consent to participate in the study. The participants received a financial compensation of 30 euros for their voluntary participation. All procedures of the study were approved by the Ethics Committee of Leiden University.

Design

During this study, a cross-sectional study design is used. This research was part of a long-term ERP/EEG study in which data were collected from February 2014. The overall research was performed at the Brain and Development Lab of the Faculty of Social Sciences at Leiden University. During the lab session various tests (computer tasks and questionnaires) were conducted with the participants. Only a subset of the data has been analyzed and discussed in the current manuscript.

On the day of the appointment, the participant was picked up and brought to the laboratory. Participants were led to believe they are playing with two peers of the same sex and age. Because the other players were not real, late-adolescents were picked up at the same time with two peers. However, they could leave immediately when the participant was in the lab. In order to make the cover story more believable, the experiment leaders supposedly had contact through telephone calls and regular check-ups with the other labs. In the lab, the experiment leader first explained the sequence of the lab session, after which an informed consent was signed. Then, the participant was allowed to sit down on the chair behind the computer where the EEG was connected. Subsequently, the participant accomplished a status-induction task and a gambling task.

Measures

Status-induction task: Social status was induced with a computer task (adapted from Zink et al., 2008). The task was an interactive game in which participants played a simple reaction time task with two (fictive) players. Participants were instructed to react as fast as possible to the change of the color of the dot presented in the middle of the screen.

A trial started with a black fixation screen in which a white asterisk was presented in the center for 400-750 ms with increments of 50 ms. After fixation a red dot was presented in the center of a black screen. After 300-2000 ms the red dot changed into a green dot. Participants were instructed to press the left button with their right hand as quickly as possible when the dot changed color. When the participant responded to the color change, the names of the three players were shown on the right side of the screen for 2500 ms. The name of the best player was presented at the top of the screen (with three stars behind the name) and the name of the worst player was presented at the bottom of the screen (with one star behind the name). The middle performing player was presented in the middle of the screen (with two stars behind the name). The rank reflected a cumulative of their performance. The participants had no insight in their performance per trial.

A social hierarchy was created by identifying the performance of the participant (Zink et al., 2008). We defined the participant as a high status player when he/she had the best performance (three star player) and a low status player when he/she had the worst performance compared to the two other (fictive) players. All participants always had a predetermined high or low status at the end of the game. The task consisted of 100 trials of which the first 80 trials reflected the actual performance of the participant based on an algorithm. The last 20 trials were programmed by the computer, according to which group the participant belongs (high or low status group).

Gambling Task: The (sensitivity to) risk-taking behavior is assessed using a gambling computer task (adapted from Gehring & Willoughby, 2002). Participants performed the task in which they could choose between two treasure chests containing a number of coins which they could win or lose. One box contained a high number of coins (e.g. 25) and the other contained a low number of coins (e.g. 5). If the chosen treasure chest turned into a plus the number of coins was stored in an imaginary bank account. However, the number of coins was deducted when the chosen treasure chest turned into a minus. The probability of winning or losing was 50% on each trial. Participants were instructed to gain as much coins as possible because they would be rewarded the coins they had won at the end of the experiment. At each trial there were consequently high and low number of coins in the treasure chests.

A trial started with a black fixation screen in which a white asterisk was presented in the center for 1200 ms. After fixation two treasure chests with a low number of coins and a high number of coins were presented in the center of a black screen. Participants were instructed to press a button with their left middle finger for choosing the left treasure chest and press a button with their left index finger for choosing the right treasure chest. When the participant responded a red circle around the chosen treasure chest was presented on the screen for 500 ms. After this screen feedback was given whether the number of coins was won or lost by presenting a plus (+) or minus (-) in the place of the chosen treasure chest for 1000 ms. In this computer task six sets of the game are presented. Each set consisted of 40 trials.

EEG data acquisition

The EEG signals were recorded using an Active-Two amplifier system (Biosemi). This system consists of 64 scalp electrodes, including Fz, F1/2, FCz, F3/4, FC1/2, FC3/4, Cz, C1/2, C3/4, CPz, Cp1/2, Pz, and P1/3. The electrodes were mounted in an elastic cap. Also six external electrodes were attached to the face of the participants: two on the left and right mastoids, two on the outer canthus of the eyes (HEOG), and two on the infraorbital and supraorbital regions of the left eye (VEOG). The online signals were recorded from DC to 134 Hz. All signals were digitized with a sample rate of 512 Hz and 24-bit A/D conversion. Offline, a mathematically average reference was applied. EEG and EOG activity was filtered with a bandpass of 0.10-30 Hz (phase shift-free Butterworth filters; 24dB/octave slope). According to the Gratton, Coles and Donchin algorithm (1983), ocular correction was applied. Artifact rejection criteria were minimum to maximum baseline-to-peak allowed voltage -100 to +100 µV. There was a maximum allowed voltage skip (gradient) of 75 µV per sample point. The data were segmented in epochs of 900 ms, from 100 ms pre-target onset to 800 ms post-target onset. For baseline correction the mean 100 ms pre-stimulus period was used. Grand averages were calculated for each condition. The FRN component (also known as the MFN component) was defined as the mean activity in the 200-250 ms time window after target presentation.

Data analysis

After the data collection, the behavioral data was analyzed using SPSS. First, a descriptive analysis was done to clarify the characteristics of the study sample and the distribution across the three age groups. Then, consideration was given at the influences and relationships between the studied variables. A frequency table was used to assess the average percentage of high choices of the participants. By means of a factorial analysis of variance (ANOVA), the influence of age group (10-13, 14-17, 18-22) and social status (low, high) (both independent variables) on making high (risky) choices (dependent variable) were examined.

In addition, the electrophysiological data was processed with Brain Vision Analyzer. Then, analyzes were performed with SPSS. A repeated measures analysis of variance with four within-subjects (win-low, win-high, loss-low, loss-high) and two between-subjects variables (age group and social status) gave insight into differences in the amplitude of the FRN (dependent variable). Also the influence of age group and social status (independent variables) were examined. Paired-samples t-tests were conducted to compare the amplitude of the FRN at FCz in gain and loss conditions and in high and low number of coins conditions for each age group and social status.

Results

Behavioral data

The average percentage of high choices was 59,69 (range = 8-96, *SD* = 18.93). The factorial analysis of variance showed a considerable trend toward significance of social status, F(1,87) = 3.33, *p* =.071. Participants with a high status selected more often high numbers of coins (instead of low numbers of coins) than participants with a low status. No significant main effect of age group (p =.162), as well as a significant interaction effect between age group and social status (p =.116) were found. The distribution of high choices, including the influence of age group and social status is depicted in Figure 2.

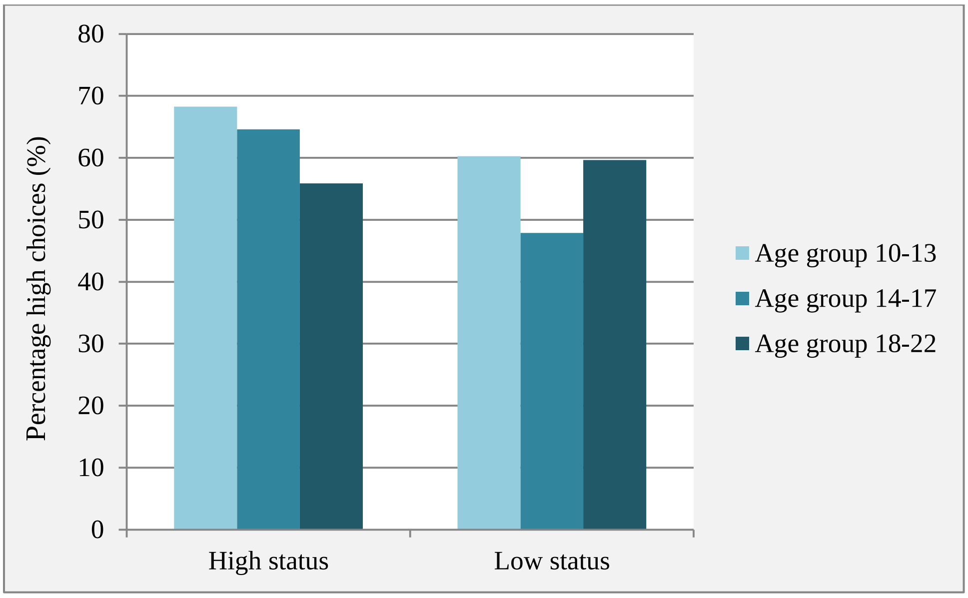

Figure 2. Percentage of high choices across the three age groups, distinguishing participants with high and low status. The considerable trend of social status is evident in the age groups 10-13 and 14-17.

Electrophysiological data

The repeated measures analysis of variance of the electrophysiological data indicated that the assumption of spehericity (Mauchly's test) had been met for the main effects of feedback (gain or loss) and number of coins (low or high), because the repeated measures variables have only two levels. Therefore degrees of freedom were not corrected.

There was a significant main effect of the type of feedback on the FRN at FCz, $F(1,57) = 34.21$, $p < .05$. The FRN was larger (more negative) after losses than after gains. Also a significant main effect of the number of coins on the FRN at FCz was found, $F(1,57) = 29.49$, $p < .05$, with more negative values for low numbers of coins than for high numbers of coins.

There was no significant interaction effect between the type of feedback and the number of coins (p =.901). This indicates that the number of coins had not different effects on the FRN depending on which type of feedback was given. Table 1 presents the estimated marginal means of the FRN at FCz, including the type of feedback and the number of coins.

Type of feedback	Means (SE)	95% confidence interval
Win	9.81 (0.68)	8.46 – 11.17
Lose	7.17 (0.59)	5.99 – 8.35

Number of coins	Means (SE)	95% confidence interval
Low number	7.51 (0.56)	6.39 – 8.64
High number	9.47 (0.67)	8.12 – 10.82

Table 1. Means (SE) and 95% confidence interval of the FRN at FCz, including the type of feedback and the number of coins.

The same analysis examined the differences between the age groups and the influence of social status. There was a significant effect of age group, $F(2,57) = 5.11$, $p < .05$, with the lowest means for the age group 10-13 years ($M = 6.39$, $SE = 0.95$), followed by the age groups 18-22 years ($M = 8.27$, $SE = 1.12$) and 14-17 years ($M = 10.81$, $SE = 1.01$), regardless the type of feedback or the number of coins. Post hoc tests using the Bonferroni correction revealed that the FRN amplitude of the age group 10-13 years was significantly different from the FRN amplitude of the age group 14-17 years (p <.05). There were no significant differences found between the age groups 14-17 years and 18-22 years (p =.315) and between the age groups 10-13 years and 18-22 years (p =.554). For social status, no significant effect was found (p =.484).

Figure 3 shows the grand averages of the FRN at FCz to gain and loss feedback of low and high numbers of coins across the three age groups for each social status. As shown in Figure 3, the FRN was significant larger after losses than after gains. This is reflected in all age groups. Different paired-samples t-tests were conducted to compare the amplitude of the FRN at FCz in gain and loss conditions for each age group and social status. For the age groups 10-13 years and 14-17 years with a low status there was a significant difference between the scores for gains and the scores for losses, $t(12) = 2.560$, $p = .025$ and $t(10) = 2.414$, $p = .036$. For high status participants in this age groups no significant differences were found. The age group 18-22 years showed at both high and low status significant differences between gains and losses, *t*(10) = 3.347, *p* = .007 and *t*(6) = 4.925, *p* =.003. In all cases, the scores for losses were more negative than the scores for gains.

The FRN was also significant larger for low numbers of coins than for high numbers of coins. Different paired-samples t-tests were conducted to compare the amplitude of the FRN at FCz in high and low number of coins conditions for each age group and social status. Only for the age groups 14-17 years with a high status and 18-22 years with a low status significant differences were found between the scores for losses of high number of coins and losses of low numbers of coins, *t*(9) = -2.842, *p* = .019 and *t*(6) = -3.268, *p* =.017. In these cases the scores for low number of coins were more negative than the scores for high number of coins.

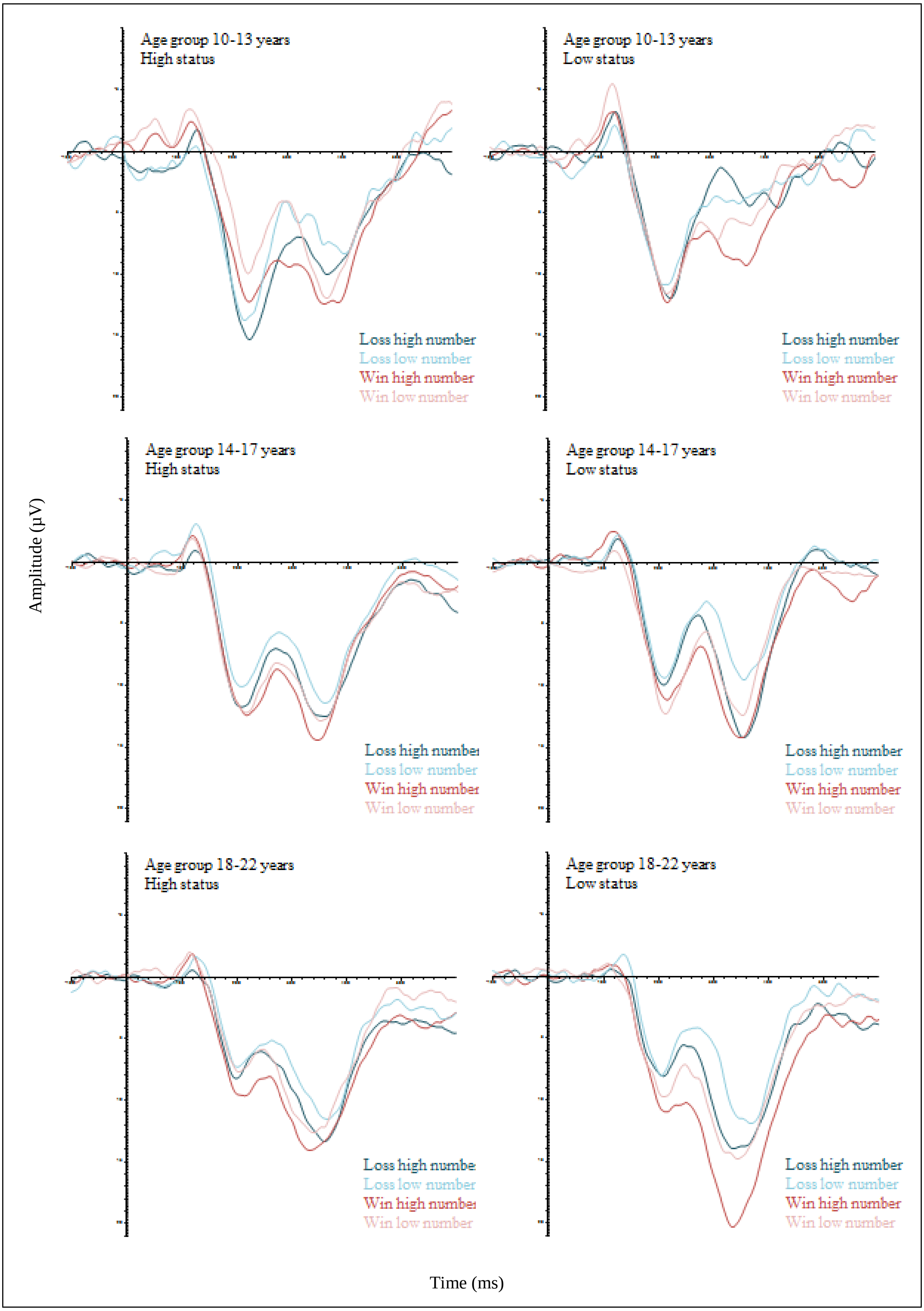

Figure 3. Grand averages of the FRN at FCz after receiving gain and loss feedback of low and high numbers of coins across the three age groups for each social status.

More important, a significant effect between the type of feedback and the social status was found, $F(1,57) = 4.31$, $p < .05$. This indicates that the social status had different effects on the FRN depending on which type of feedback was given. The FRN was larger (more negative) after losses for participants with a low status than for participants with a high status. In addition, the FRN was slightly larger after gains for participants with a high status than for participants with a low status. Table 2 presents the estimated marginal means of the FRN at FCz, which distinguishes the social status and type of feedback.

Other significant interaction effects (related to the number of coins and the different age groups) were not found.

	Means (SE)	95% confidence interval
Low status		
Win	9.86 (0.98)	7.90 – 11.82
Lose	6.29 (0.85)	4.58 – 8.00
High status		
Win	9.76 (0.93)	7.89 – 11.63
Lose	8.06 (0.81)	6.43 – 9.69

Table 2. Means (SE) and 95% confidence interval of the FRN at FCz, distinguishing the social status and type of feedback.

Discussion

The aim of this cross-sectional ERP/EEG study was to investigate developmental differences of risk-taking behavior in normally developing adolescents across three age groups with a high or low status. First, the average percentage of high choices was assessed. Results showed a higher average percentage for high choices, which indicates that adolescents (regardless of age and social status) are indeed more likely to take risks rather than to play safe. There was no significant effect of age group. Although there are major differences in the literature about the amount of risk-taking behavior during adolescence, based on the results of this research it is not possible to draw any conclusions about the differences between the age groups. However, it can be concluded that there is an influence of social status. A considerable trend toward significance showed that high status participants selected more often high choices than low status participants. This result corresponds with the formulated hypothesis. Based on the study of Allen and his colleagues it was expected that high status adolescents will take more risks than low status adolescents. Popular or high status adolescents appear to be more sensitive to higher levels of risky decisions. This could express itself into increasing problematic behavior such as higher levels of alcohol and substance abuse involvement and minor deliquent behavior (Allen et al., 2005).

When examining the amplitudes of the FRN, the results showed effects of the type of feedback (gain or loss) and the number of coins (high or low). The FRN was larger after losses than after gains and larger for low number of coins than for high number of coins. These results are consistent with those that had been expected. It was hypothesized that the FRN amplitudes were larger in losing instead of winning (Grose-Fifer et al., 2014; Zotolli & Grose-Fifer, 2012; Santesso et al., 2011; Hämmerer et al., 2010; Yeung & Sanfey, 2004; Gehring & Willoughby, 2002) and larger for low than for high outcomes (Grose-Fifer et al., 2014; Santesso et al., 2011). Although some studies have showed that the amplitude of the FRN have no reliable relationship to the magnitude of rewards associated with feedback (Gehring & Willoughby, 2002; Yeung & Sanfey, 2004), the results of this study thus suggest an effect of the magnitude or amount of the feedback (high or low), as well as an effect of the direction of the feedback (gain or loss).

The FRN is seen as a rapid cognitive system of performance feedback that reflects neural processes of ongoing events (Gehring & Willoughby, 2002; Nieuwenhuis, Slagter, von Geusau, Heslenfeld, & Holroyd, 2005; Santesso et al., 2011). This evaluative neural activity in the brain appears to be related to the affective and behavioral control functions of the anterior cingulate cortex (ACC) and the mesencephalic dopamine system (Gehering & Willoughby, 2002; Nieuwenhuis et al., 2005; Ferdinand & Kray, 2014). Larger amplitudes in loss conditions compared to gain conditions indicate greater activity and suggest that adolescents are relatively more sensitive for negative feedbacks or bad outcomes. Feedback of low number of coins instead of high number of coins could be associated with unfavorable outcomes. A previous study noted that a small win is not as good as a large win (Grose-Fifer et al., 2014). This outcome thus is worse relative to the other possible outcome and may explain the greater activity for low numbers of coins. However, in the case of losses (e.g. a small loss is not worse than a large loss), it is not clear why greater activity arise. These results may suggest that the FRN is not just an evaluation of the magnitude of the received feedback, but rather a relative evaluation of possible outcomes along the dimensions of valence or likelihood of occurrence (Hämmerer et al., 2010).

Furthermore, it was interesting to see whether social status affects the feedback processing of adolescents. Previous findings showed that social status has an effect on how people evaluate their own performance (Boksem et al., 2012). It was expected that adolescents with a low status would be more sensitive to gains and losses than adolescents with a high status. The results of this study are consistent with previous research considering negative outcomes (losses). In these cases, low status participants showed a greater activity for feedback outcomes than high status participants. This result may suggest that low status individuals are more concerned about making mistakes than high status individuals. In contrast, an opposite effect turned out in the case of positive outcomes (gains). There was a slightly larger activity for high status participants than for low status participants. This contrast could be explained because high status individuals are more focused on rewarding outcomes, whereas low status individuals are more likely to evaluate their outcomes in terms of potential threat (Boksem et al., 2012).

With regard to the electrophysiological data, the results showed a significant effect of age group, regardless the direction of the feedback and the magnitude or amount of the feedback. The greatest sensitivity for the age group 10-13 years and the significant difference with the age group 14-17 years correspond to the study of Hämmerer and her colleagues. Based on their study it was expected that the sensitivity to positive and negative outcomes would decrease with increasing age (Hämmerer et al., 2010). Due to a lack of significant differences with the age group 18-22 years, it is not possible to draw the conclusion whether if the decrease continues into the late adolescence. These results are inconsistent with the neurobiological model, which reflects a nonlinearity of emotion systems and cognitive control systems. This model suggests that the emotional and action-regulating systems develop earlier than the control signaling systems, which is thought to be reflected in increasing (sensitivity to) risky behavior during mid adolescence (Somerville et al., 2010; Casey et al., 2008). A possible explanation for this contrast could be found in the fact that children are more sensitive to negative feedbacks (Eppinger, Mock, & Kray, 2009) and appear to be more responsive to external feedback in general (Ferdinand & Kray, 2014). They experience the feedback as more emotional or motivating than older adolescents or adults (Ferdinand & Kray, 2014), which is showed in increased sensitivity.

Due to a lack of an interaction effect with the age group it is not possible to conclude anything about the differences between the age groups with regard to the direction of the feedback and the magnitude of rewards associated with feedback.

It is important to take into account some limitations of this research that may be related to the lack of significant results. First, the sample size is not large enough. Although the sample is truly random, the results should definitively have a greater impact when there participated more adolescents in each age group. Studies of Hämmerer and colleagues (2010), and Grose-Fifer and colleagues (2014) showed significant differences between age groups with regard to the FRN amplitudes in positive and negative outcomes, and in high and low magnitude of rewards associated with feedback. In their studies, approximately 40 adolescents participated in each age group, whereas approximately 20 adolescents participated in each age group in this current research. Due to recording or technical problems, or because participants did not commit enough gain or loss trials, 30 participants were excluded for the EEG analyses. Larger groups could show differences between the different phases of adolescence, which may increase understanding of the development of feedback processing during adolescence.

In addition, also gender differences could be assessed, which lead to another limitation of this research. The distribution of males and females were not equal for the three different age groups. Adolescence starts usually 1-2 years earlier in girls than in boys (Crone & Dahl, 2012), suggesting there may be gender differences. This is confirmed in an earlier study that showed that males perceived behavior as less risky, took more risk, were less sensitive to negative outcomes and were less socially anxious than females (Reniers, Murphy, Lin, Bartolomé, & Wood, 2016). Also animal studies suggested that the midbrain dopamine system develops differentially in males and females. Gender differences in risk-taking behavior may be related to differences in the processing of external feedback (Zotolli & Grose-Fifer, 2012). For this reason it is important to keep this in mind for future studies. However, in this current study, it was not achievable to take gender differences into account because the age groups would then be far too small.

In conclusion, this study has shown that adolescents are more likely to take risks rather than to play safe. Important here is the influence of social status. Popular or high status adolescents appear to be more sensitive to higher levels of risky decisions. Importantly, the neural activity of feedback processing is modulated differently in positive and negative outcomes, and in high and low magnitude of rewards associated with feedback. Adolescents appear to be more sensitive to negative feedbacks or bad outcomes and low magnitudes of rewards than positive and high outcomes. In case of negative feedbacks, low status adolescents showed greater activity than high status adolescents, suggesting that low status individuals are more concerned about making mistakes and evaluate their outcomes, whereas high status individuals are more focused on rewarding outcomes. Looking at the different phases of adolescence it can be concluded that the sensitivity to feedback, whether positive or negative, decreases in the transition from early adolescence to mid adolescence. The findings of this research are consistent with earlier studies. An important goal for future research will be to examine developmental and gender differences in risk-taking behavior among a larger group of adolescents taking into account differences in the feedback processing after positive and negative outcomes, and after high and low magnitude of rewards associated with feedback.

Acknowledgments

This master thesis is written within the context of the master Child and Adolescent Psychology, followed at Leiden University. Interest for this research has arisen when looking for a project with new possibilities, such as ERP/EEG research. In February 2015 I started with this master project. Both the data collection with two different bachelor groups and writing this thesis has been an educational time for me. I gained more insight into conducting scientific ERP/EEG research in practice. Although I have been busy writing my thesis for a long period of time, I would like to thank a few people who have contributed to this end result. First of all, I would like to thank my supervisor, Kiki Zanolie. Her accompaniment and feedback helped me to complete this master thesis in a good way. I would also like to thank Laura Steinberg. Firstly because the fun and cosines had ensured an unforgettable time. But she was also always there for help and feedback. Finally, I would like to thank my family and friends. Without their support and love, this thesis had never been so successful.

Karine van Schie, August 2017

References

Allen, J.P., Porter, M.R., McFarland, F.C., Marsh, P., & McElhaney, K.B. (2005). The two faces of adolescents' success with peers: Adolescent popularity, social adaptation, and deviant behavior. *Child Development, 76*(3), 747-760.

Badaly, D. & Schwartz, D. (2012). Social status, perceived social reputations, and perceived dyadic relationships in early adolescence. *Social Development, 21*(3), 482-500.

Begen, F.M. & Turner-Cobb, J.M. (2011). The need to belong and symptoms of acute physical health in early adolescence. *Journal of Health Psychology, 17*(6), 907-916.

Boksem, M.A.S., Kostermans, E., Milivojevic, B., & De Cremer, D. (2012). Social status determines how we monitor and evaluate our performance. *SCAN, 7,* 304-313.

Braams, B.R., van Leijenhorst, L., & Crone, E.A. (2014). Risks, rewards, and the developing brain in childhood and adolescence. In V.F. Reyna & V. Zayas (Eds.) *The neuroscience of risky decision making.* Washington DC: American Psychological Association.

Braams, B.R., Peters, S., Peper, J.S., Güroğlu, B., & Crone, E.A. (2014). Gambling for self, friends, and antagonists: Differential contributions of affective and social brain regions on adolescent reward processing. *Neuroimage, 100,* 281-289.

Casey, B.J., Getz, S., & Galvan, A. (2008). The adolescent brain. *Developmental Review, 28,* 62-77.

Crone, E.A. & Dahl, R.E. (2012). Understanding adolescence as a period of social-affective engagement and goal flexibility. *Neuroscience, 13,* 636-650.

Crone, E.A. & Güroğlu, B. (2013). Development of emotion and social reasoning in adolescence. Oxford Handbook of Cognitive Neuroscience.

Dahl, R.E. (2004). Adolescent brain development: A period of vulnerabilities and opportunities. Keynote address. *Annals of the New York Academy of Sciences, 1021,* 1-22.

Duijvenvoorde, A.C.K. van, Macks, Z.A. Op de, Overgaauw, S., Gunther Moor, B., Dahl, R.E., & Crone, E.A. (2014). A cross-sectional and longitudinal analysis of reward-related brain activation: Effect of age, pubertal stage, and reward sensitivity. *Brain and Cognition, 89,* 3-14.

Eppinger, B., Mock, B., & Kray, J. (2009). Developmental differences in learning and error processing: Evidence from ERPs. *Psychophysiology, 46,* 1043-1053.

Feldman, R.S. (2009). Ontwikkelingspsychologie. Pearson Education Benelux.

Ferdinand, N.K. & Kray, J. (2014). Developmental changes in performance monitoring: How electrophysiological data can enhance our understanding of error and feedback processing in childhood and adolescence. *Behavioural Brain Research, 263,* 122-132.

Gehring, W.J. & Willoughby, A.R. (2002). The medial frontal cortex and the rapid processing of monetary gains and losses. *Science, 295,* 2279-2282.

Gratton, G., Coles, M.G.H., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and clinical Neurophysiology, 55,* 468-484.

Grose-Fifer, J., Migliaccio, R., & Zottoli, T.M. (2014). Feedback processing in adolescence: An event-related potential study of age and gender differences. *Developmental Neuroscience, 36,* 228-238.

Hämmerer, D., Li, S., Müller, V., & Lindenberger, U. (2010). Life span differences in electrophysiological correlates of monitoring gains and losses during probabilistic reinforcement learning. *Journal of Cognitive Neuroscience, 23,* 579-592.

Kalat, J.W. (2013). *Biological Psychology.* Wadsworth: Cengage Learning.

Koolschijn, P.C.M.P. & Crone, E.A. (2013). Sex differences and structural brain maturation from childhood to early adulthood. *Developmental Cognitive Neuroscience, 5,* 106-118.

Knack, J.M., Jacquot, C., Jensen-Campbell, L.A., & Malcolm, K.T. (2013). Importance of having agreeable friends in adolescence (especially when you are not). *Journal of Applied Social Psychology, 43,* 2401-2413.

Nieuwenhuis, S., Slagter, H.A., von Geusau, N.J.A., Heslenfeld, D.J., & Holroyd, C.B. (2005). Knowing good from bad: differential activation of human cortical areas by positive and negative outcomes. *European Journal of Neuroscience, 21,* 3161-3168.

Peper, J.S., Koolschijn, P.C.M.P., & Crone, E.A. (2013). Development of risk taking: Contributions from adolescent testosterone and the orbito-frontal cortex. *Journal of Cognitive Neuroscience, 25*(12), 2141-2150.

Reniers, R.L.E.P., Murphy, L., Lin, A., Bartolomé, S.P., & Wood, S.J. (2016). Risk perception and risk taking behaviour during adolescence: The influence of personality and gender. *PLOS ONE, 1-14.*

Rubin, K., Fredstrom, B., & Bowker, J. (2008). Future directions in … friendship in childhood and early adolescence. *Social Development, 17*(4), 1085-1096.

Santesso, D.L., Dzyundzyak, A., & Segalowitz, S.J. (2011). Age, sex and individual differences in punishment sensitivity: Factors influencing the feedback-related negativity. *Psychophysiology, 48,* 1481-1488.

Somerville, L.H., Jones, R.M., & Casey, B.J. (2010). A time of change: Behavioral and neural correlates of adolescents sensitivity to appetitive and aversive environmental cues. *Brain and Cognition, 72,* 124-133.

Steinberg, L. (2008). A social neuroscience perspective on adolescent risk-taking. *Developmental Review, 28,* 78-106.

Woodhouse, S.S., Dykas, M.J., & Cassidy, J. (2011). Loneliness and peer relations in adolescence. *Social Development, 21*(2), 273-293.

Yeung, N. & Sanfrey, A.G. (2004). Independent coding of reward magnitude and valence in the human brain. *The journal of neuroscience, 24*(28), 6258-6264.

Zink, C.F., Tong, Y., Chen, Q., Bassett, D.S., Stein, J.L., & Meyer-Lindenberg, A. (2008). Know your place: Neural processing of social hierarchy in humans. *Neuron, 58,* 273-283.

Zottolli, T.M. & Grose-Fifer, J. (2012). The feedback-related negativity (FRN) in adolescents. *Psychophysiology, 49,* 413-420.