Adolescent aggressive behavior

Sijtsema, J.J.

CHAPTER 4

Resting heart rate and (pre)adolescent antisocial behavior: Interactions with the peer context

Abstract

Low resting heart rate is associated with and predictive of antisocial behavior. Previous studies suggest that this relationship may be moderated by peer context. From a person-environment interaction perspective, it can be hypothesized that low resting heart rate in preadolescence is positively associated with antisocial behavior in adverse peer contexts, whereas being in a supportive peer context would have a buffering effect. Furthermore, analyses were adjusted for family context (i.e., family break-up and SES). Data come from a subsample of the TRAILS study (N=1753; 48.5% boys). Peer context was assessed using peer-assessed behavior of classmates and friends on support and bullying/antisocial behavior. Regression analyses showed that low resting heart rate in preadolescence and peer context were associated with antisocial behavior. Moreover, interactions indicated that low resting heart rate was only associated with antisocial behavior in preadolescents in adverse peer contexts. Low resting heart rate was also predictive of boys' antisocial behavior in adolescence, irrespective of classmates' and friends' pro- and antisocial behavior, family context, and earlier antisocial behavior. To conclude, we found support for a person-environment interaction in preadolescence: the relationship between low resting heart rate and antisocial behavior was only present in adverse peer contexts.

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4.1. Introduction

Low resting heart rate (HR) is one of the most replicated biological correlates of antisocial behavior (ASB) in childhood and adolescence (Ortiz & Raine, 2004). This relationship has typically been ascribed to various underlying emotional and temperamental mechanisms, such as fearlessness and sensation seeking and is in general characterized as an indication of physiological underarousal. Empirical evidence also largely supports this direction of effects (Scarpa et al., 1997; Sijtsema et al., 2010b). However, there are two major issues that have not been addressed before. First, it has been suggested that the relationship between resting HR and ASB does not solely rest on temperamental mechanisms but is to some extent influenced by the social environment as well (Dodge & Pettit, 2003; Scarpa & Raine, 2006). More specifically, Dodge and Pettit (2003) argue that 'certain risk factors exert influence only in the presence (or absence) of another risk factor (or, at least, the magnitude of risk associated with one factor varies across levels of another factor)' (pp: 354). In the current study we address such a person-environment interaction by assessing the effect of the individual risk factor biological underarousal, assessed via low resting HR, on ASB in the presence of peer contexts characterized by supportive and antisocial peer behaviors. We argue that youth characterized by underarousal may be more susceptible to the negative influences of the peer context, whereas positive influences may buffer the association between underarousal and ASB. The second issue we address is testing this biological susceptibility to peer context while accounting for family contextual factors, i.e., family break-up and socioeconomic status (SES). Both factors are known to play a major role in the explanation of ASB (e.g., Armstrong et al., 2009; Ary et al., 1999).

Resting Heart Rate and Antisocial Behavior

Whereas low resting HR has typically been associated with higher levels of ASB, such as aggression, delinquency, and crime (Dietrich et al., 2007; Ortiz & Raine, 2004; Wadsworth, 1976), it has also been shown to predict ASB in adolescence (Bimmel et al., 2008; Raine et al., 1997). Theoretically, there are several explanations for the relationship between resting HR and ASB. One suggestion is that low resting HR is associated with high levels of fearlessness (Raine, 2002), resulting in poor conditioning to punishment which may lead to the development of ASB. However, it has also been suggested that low resting HR is an indicator of underarousal and may thus predispose to stimulation seeking to raise autonomic activity to a more optimal state (Raine et al., 1997; Sijtsema et al., 2010b). Engaging in ASB may be one viable alternative to fulfill the need for stimulation seeking and subsequently reaching a more optimal physiological state. In this case, low resting HR individuals would be particularly susceptible to the high-stimulation end of the environmental spectrum. In line with this stimulation seeking theory, youth with low resting HR may feel more at home with antisocial peers, who engage more in exciting and risky activities which can lead to elevated HR levels. Evidence from the research field on peer relationships also shows that deviant peers influence individual behavior with regard to ASB (Ary et al., 1999; Patterson et al., 1989), delinquency (Burk et al., 2007;

Vitaro et al., 2007), and aggression (Sijtsema et al., 2010a). These studies not only show that antisocial youth socialize their members in terms of behavior, but sometimes also select themselves into groups with similar peers.

In sum, these assumptions presume that an unfavorable socialization in combination with a heightened biological susceptibility to adverse high-stimulation environments may be associated with more negative outcomes. In other words, we hypothesize that preadolescents with low resting HR in contexts characterized by antisocial peers will display higher levels of ASB.

However, whereas antisocial peer contexts may be regarded as an additional risk factor, supportive peer contexts may buffer the association between low resting HR and ASB. Among peers who value affection and support, ASB could lead to rejection and a loss of status, in this way reducing access to important goals of subjective well-being (see e.g., Lindenberg, 1996). The peer context could therefore also play a protective role and youth who are biologically more susceptible to stimulation seeking are then in fact shielded from the negative effects of their underaroused disposition (cf. Boyce & Ellis, 2005). We thus hypothesize that the association between low resting HR and ASB may be buffered by contexts characterized by supportive peers.

Gender differences

Next to the aforementioned variability in biological susceptibility to peer contexts, we expect differences between boys and girls. Small to moderate effect sizes for both cross-sectional and longitudinal relationships between HR and ASB have been found consistently in adolescent boys (Ortiz & Raine, 2004). In adolescent girls, however, findings are at the most mixed. To our knowledge there are only two studies, focusing specifically on girls, which have shown an association between low resting HR and ASB. The first study comprised 15-year old girls (N=36) who were rated on antisociality by their teachers (Bullock, 1988). The other study included 12.5-year old girls (N=44) who were teacher-rated on disruptive behavior (Maliphant et al., 1990). Both studies were cross-sectional and comprised a small sample. Moreover, there is more and stronger evidence (e.g., larger samples) that fails to replicate that low resting HR is related to ASB in adolescent girls (Crozier et al., 2008; Rogeness et al., 1990; Sijtsema et al., 2010b).

To conclude, only in boys we expected effects of heightened biological susceptibility, measured as low resting HR, to negative peer contexts on individual ASB. More specifically, we expected that low resting HR would be positively associated with ASB in adverse peer contexts (characterized by peer-rated bullying, fighting or rule breaking behavior). In contrast, we expected that the negative association between resting HR and ASB would be buffered by supportive peer contexts. In the current study peer context was assessed as peer-rated behavior of classmates (i.e., *classroom behavior*) and nominated friends (i.e., *friends' behavior*). Moreover, we expected that these person-environment interactions would hold after accounting for family context as assessed via family breakup and SES. In the prospective analyses we also controlled

for earlier levels of individual ASB, to see whether heart rate had an effect on increases in individual ASB.

4.2. Method

Subjects

Data were collected in a general population study called TRAILS (TRacking Adolescents' Individual Lives Survey), a large prospective population study of Dutch adolescents with bi- or triennial measurements from age 11 to at least early adulthood (Huisman et al., 2008; Oldehinkel et al., 2004). Parental informed consent was obtained after the procedures had been fully explained. Detailed information about sample selection and analysis of non-response bias has been reported elsewhere (De Winter et al., 2005). The three assessments waves ran from March 2001 to July 2002 (T1), September 2003 to December 2004 (T2), and September 2005 to December 2007 (T3). At T1, 2230 children (mean age = 11.09, SD = 0.56) enrolled in the study of whom 2149 (96.4%; mean age 13.56, SD = 0.53) participated at T2 and 1816 (81.4%; mean age 16.27, SD = 0.73) at T3.

Measures

Antisocial behavior (ASB). Antisocial behavior was assessed with the self-reported Antisocial Behavior Questionnaire (ASBQ; Moffitt & Silva, 1988) at age 11 (T1), 13.5 (T2), and 16 (T3). Participants responded on a five-point scale ('no, never' to 'seven or more times') whether they had partaken in antisocial activities, such as stealing, fighting, and damaging things (26-28 items; α's > .86).

Heart rate (HR). At age 11, cardiac autonomic function was assessed by a three-lead electrocardiogram, while participants were in supine position and breathing spontaneously. Dedicated software ([pre-]CARSPAN, previously used in e.g. Dietrich et al., (2007)) was used to detect R-peaks, to check signal stationarity, to correct for artifacts, and to calculate the interbeat-interval (IBI; in milliseconds) between two heartbeats. IBI is inversely related to HR by the equation HR = 60000/IBI. HR was expressed in beats per minute (bpm). Blocks were considered invalid if they contained artifacts with a duration of more than 5 seconds, if the total artifact duration was more than 10% of the registration, or if the block length was less than 100 seconds. Heart rate recordings were missing (n = 76) due to recording failure (41%) or signal-analysis failure (59%). HR was collected from 1753 (78.6%) TRAILS participants. These participants differed from the whole TRAILS population in that they were slightly younger at T1 (t = 10.66, p < .001), less antisocial at T1 and T2 (ts > 2.51, ps < .05), and tended to come less often from broken families at T1 (t = 1.89, p < .06).

Peer context at T1. Peer context was measured by assessing peer behavior in a subsample of 1065 (47.8%) TRAILS participants. In 50.1% of these participants we also assessed resting HR. Classrooms with at least ten regular TRAILS participants were included in the subsample. Children in special education, in small schools, and who repeated or skipped a grade were

excluded from the subsample. A previous study showed that the subsample contained fewer children who were at risk for, amongst others, aggression and coming from adverse family contexts than the full TRAILS sample (Veenstra et al., 2005). Findings in the current study may thus be slightly underestimated compared to the whole TRAILS sample.

Peers nominated their classmates on providing *emotional support* and *bullying behavior* by responding respectively to the question 'which classmates give you emotional aid when you are despondent (e.g. problems at home)?' and 'by whom are you bullied?'. Respondents could make unlimited nominations across gender within the classroom. Subsequently, nominations were added up and divided by the number of possible nominations within the classroom to obtain an individual measure of peer emotional support and peer bullying behavior. Next, these individual scores were aggregated to obtain a measure of classroom emotional support and bullying behavior. These aggregated scores were used in the analyses. To assess friends' behavior, respondents were also asked 'Which classmates are your best friends?' (unlimited nominations). This way we were able to distinguish between classmates' and friends' emotional support and bullying behavior.

Peer context at T2. Peer context was measured by assessing peer behavior in a subsample including 1007 TRAILS participants (46.9% of the total sample at T2) and their classmates. For 53.9% of these participants resting HR data at T1 was also available. Classrooms with at least three regular TRAILS participants were included, leading to participation of a total of 172 classes in 34 schools in first (72 school classes) and second grade (100 school classes) of secondary education (Dijkstra et al., 2008).

Peers nominated their classmates on *providing support* (i.e., two items measuring practical and emotional support) and *antisocial behavior* (i.e., three items measuring bullying behavior, fighting, and rule-breaking). Respondents could make unlimited nominations across gender within the classroom. Subsequently, the same procedure as described for the T1 peer nominations was applied. In addition, these scores were standardized to obtain individual measures of peer support and antisocial behavior. Next, for classroom behavior these scores were aggregated to obtain a measure of classroom support and antisocial behavior. Similar to the procedure at T1, to assess friends' behavior, respondents were also asked 'Which classmates are your best friends?' (unlimited nominations).

Family context. Socioeconomic status (SES) was assessed at T1 by creating a scale consisting of parents' education, job, and household income (α = .84). Continuous scores of SES were used. Furthermore, parents were interviewed about their family situation at T1. Parents could indicate whether they were divorced, lived in a single-parent household, or whether the child had a step-parent. These three measures were combined into a categorical family breakup measure (0=no, 1=yes).

4.3. Data Analysis

First, we calculated descriptive statistics of all the study variables and the correlations between them. To test for gender differences chi-square analysis and independent sample *t*-tests were used. Second, to examine the associations between resting HR and peer context and ASB, multiple linear regressions were used. Effects for classroom and friends' behavior were estimated in separate regression models. In the cross-sectional analyses at T1, we included gender, age, family context (i.e., family break-up and SES), and main effects of resting HR and peer context (i.e., either classroom or friends' behavior) in the first step to predict ASB. In the prospective analyses we included peer context at T2 and furthermore controlled for earlier ASB. Step two included adding two-way interactions between HR and peer context to the model. When significant interaction effects emerged, we calculated simple slopes to test whether resting HR affected ASB at different levels of classroom and friends' behavior (Aiken & West, 1991). Furthermore, we plotted interactions using a template available at http://www.jeremydawson.co.uk/slopes.htm. To make sure that the values in Figures 1 and 2 are accurate representations of the data, we standardized the continuous independent variables (i.e., resting HR, classroom and friend behavior) and control variables (i.e., age, family breakup, SES, and ASB at T1) to a mean of zero and a standard deviation of one. As noted in the measures section, in about fifty percent of the cases we had HR assessments during rest but no peer context data. To avoid misinterpretation of the available data, we imputed missing data on ASB, peer context, and family context using multivariate multiple imputations (n = 5) with the ICE-method in STATA 9.0 Special Edition (Royston, 2004).

4.4. Results

Descriptive analyses

Table 4.1 shows summary statistics of all study variables. About one-fifth of the boys and girls came from broken families. Independent sample *t*-tests further showed that boys and girls did not differ in age and SES. At T1, girls scored on average three to four beats per minute higher on HR than boys. At T2, girls reported being more often in less supportive and antisocial classrooms. At both ages gender differences with regard to peer context were present: girls nominated more supportive friends, whereas boys nominated more bullying or antisocial friends. At all ages boys scored higher on individual ASB than girls.

Correlations are presented in Table 4.2. Being older was associated with being in a more emotionally supportive classroom, nominating more supportive friends, and more ASB. Furthermore, lower resting HR was associated with more bullying friends and ASB, although there were some differences between boys and girls. In general, classroom and friends' behaviors correlated in the expected directions. However, classroom supportive behavior at T2 correlated positively with friends' bullying behavior at T1.

Table 4.1 *Means, Standard Deviations, and Gender Differences of Control Variables, Resting Heart Rate, Friends' Behavior, and Antisocial Behavior*

	Girls (N=902)		Boys (N=851)		Gender differences
	Mean (SD)	Range	Mean (SD)	Range	
Age (years) at T1	11.01 (0.51)	10.00-12.00	11.04 (0.51)	10.00-12.00	t = -0.98, df = 1751, p = .33
Family breakup at T1	23.9%	-	21.6%	-	X^2 = 1.31, p = .26
Socioeconomic status at T1	-0.02 (0.77)	-1.94-1.73	-0.07 (0.78)	-1.85-1.72	t = 1.38, df = 1751, p = .17
Heart rate at 11 (beats per minute)	79 (11.05)	49-117	75 (10.60)	50-112	t = 6.49, df = 1751, p < .001
Classroom emotional support at T1	0.20 (0.07)	0.06-0.46	0.20 (0.06)	0.06-0.46	t = -0.56, df = 1751, p = .58
Classroom bullying behavior at T1	0.07 (0.03)	0.00-0.26	0.07 (0.03)	0.00-0.24	t = 0.46, df = 1751, p = .64
Friends' emotional support at T1	0.25 (0.09)	0.00-0.60	0.20 (0.08)	0.00-0.53	t = 13.16, df = 1751, p < .001
Friends' bullying behavior at T1	0.04 (0.03)	0.00-0.30	0.09 (0.06)	0.00-0.51	t = -24.25, df = 1751, p < .001
Classroom support at T2	0.00 (0.04)	-0.13-0.20	0.01 (0.03)	-0.14-0.14	t = -6.33, df = 1751, p < .001
Classroom antisocial behavior at T2	-0.06 (0.07)	-0.15-0.11	-0.05 (0.05)	-0.26-0.07	t = -2.45, df = 1751, p < .05
Friends' support at T2	0.62 (0.44)	-1.39-2.31	0.32 (0.47)	-1.90-1.65	t = 13.83, df = 1751, p < .001
Friends' antisocial behavior at T2	0.08 (0.43)	-0.93-1.83	0.27 (0.43)	-0.77-3.19	t = -9.22, df = 1751, p < .001
Antisocial behavior at T1	0.20 (0.22)	0.00-2.65	0.41 (0.39)	0.00-2.84	t = -13.80, df = 1751, p < .001
Antisocial behavior at T2	0.21 (0.24)	0.00-1.62	0.36 (0.37)	0.00-2.77	t = -9.73, df = 1751, p < .001
Antisocial behavior at T3	0.18 (0.24)	0.00-2.32	0.32 (0.36)	0.00-3.12	t = -10.23, df = 1751, p < .001

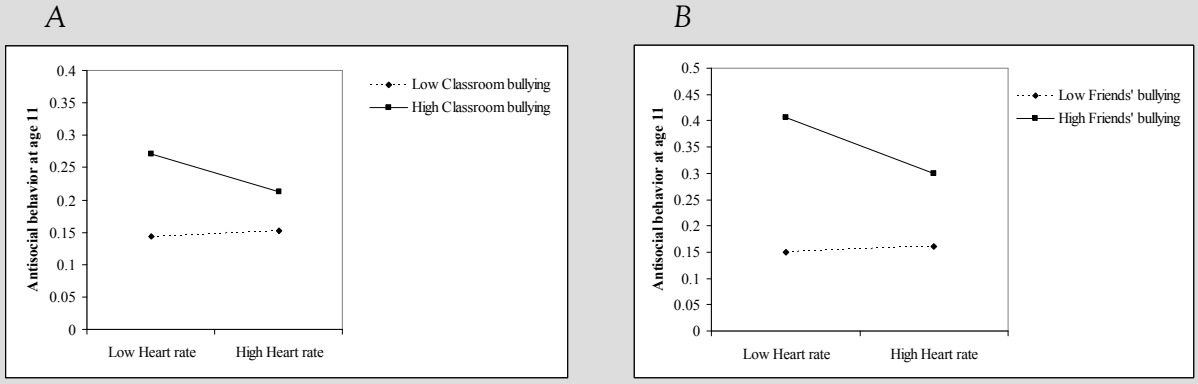
Cross-sectional analyses

Table 4.3 presents the cross-sectional results of the multiple regression analyses for the prediction of ASB at T1 separately for peer-rated classroom and friends' behavior. Main effects indicated that being older, male, having a low SES, and coming from a broken family were associated with more ASB at T1. Resting HR was negatively associated with ASB, irrespective of family context and classroom behavior. Classroom bullying behavior was positively associated with ASB at T1. With regard to friends' behavior results were similar with the exception that HR was not associated with ASB. Moreover, nominating more emotionally supportive friends was associated with less ASB.

In the second step we included the interactions between HR and gender and HR and peer context to test whether adverse and supportive peer contexts would moderate the association between resting HR and ASB. Figure 4.1 shows the significant interaction between classroom bullying behavior and resting HR. Simple slopes analysis indicated that the negative relationship between resting HR and ASB was significant in classrooms with high levels of bullying behavior (b = -0.04, t = -3.31, p < 0.01). In classrooms with low levels of bullying behavior, resting HR was not related to ASB (b = 0.00, t = 0.05, p = 0.96). Likewise, Figure 4.2 shows the interaction with regard to friends' behavior. Individuals with friends rated high on bullying showed a negative relationship between resting HR and ASB (b = -0.04, t = 3.42, p < 0.001). In contrast, for individuals who nominated friends low on bullying, resting HR was not

related to ASB (b = 0.01, t = 1.14, p = 0.26). No significant interactions were found with regard to classroom and friends' emotional support. We also tested for three-way interactions between HR, gender and peer contexts, but none of these were significant.

Figure 4.1 *Interaction Effect of Heart Rate and Classroom Bullying (Figure 4A) and Friend's Bullying Behavior (Figure 4B) on Antisocial Behavior at T1*



Prospective analyses

To test the prospective effect of resting HR on ASB, we conducted multiple regression analyses while controlling for earlier ASB (see Table 4.4). In the first step, results indicated that coming from a broken family and earlier ASB contributed to more ASB at T2. Moreover, in the classroom behavior model, being a boy and classroom support were associated with more individual ASB, whereas classroom ASB was associated with *less* individual ASB. In contrast, in the model including friends' behavior, friends' ASB at T2 was positively associated with more individual ASB. To test our hypotheses regarding the moderating roles of classroom and friends' behavior, we added interactions to the models in the second step. Whereas there were no significant interaction effects regarding peer context, gender interacted significantly with HR. These indicated that low resting HR at T1 was positively associated with boys' individual ASB two-and-a-half years later (b = -0.02, p < 0.05 in the classroom behavior model and marginally significant b = -0.03, p < 0.10 in the friends' behavior model).

Although we did not measure peer context at T3, findings with regard to ASB at age 16 also showed that low HR at T1 predicted higher levels of ASB five years later, irrespective of family context at T1, peer context at T2, and earlier ASB at T1. However, these effects were only significant for boys (b = -0.03, p < 0.01 in the classroom behavior model and b = -0.03, p < 0.05 in the friends' behavior model).

Table 4.2 *Correlations between Age, SES, Resting Heart Rate, Friends' Behavior, and Antisocial Behavior (Girls Above and Boys Below the Diagonal)*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Age (years) at T1	-	-0.05	-0.06	0.19**	-0.02	0.14**	-0.00	0.07*	-0.02	-0.03	-0.03	0.07*	0.07*	-0.04
2. Socioeconomic status (SES) at T1	-0.08*	-	-0.01	-0.13**	-0.16**	-0.02	-0.23**	-0.12**	0.09**	-0.04	-0.14**	-0.12**	-0.13**	-0.21**
3. Heart rate (beats per minute) at T1	0.03	0.07*	-	0.00	-0.02	0.01	-0.09**	-0.07*	-0.01	0.03	0.03	-0.07*	-0.01	0.00
4. Classroom emotional support at T1	0.22**	-0.13**	0.02	-	0.21**	0.79**	0.13**	0.06	0.06	-0.06	-0.08*	0.06	0.03	0.02
5. Classroom bullying behavior at T1	0.05	-0.23**	-0.41	0.22**	-	0.19**	0.49**	0.11**	0.01	0.02	-0.01	0.11**	0.02	0.02
6. Friends' emotional support at T1	0.09**	-0.01	0.02	0.77**	0.05	-	0.01	-0.05	0.05	0.03	-0.09**	-0.05	-0.02	-0.04
7. Friends' bullying behavior at T1	0.09**	-0.21**	-0.08*	0.19**	0.75**	-0.04	-	0.23**	-0.04	-0.02	0.06	0.23**	0.15**	0.15**
8. Classroom support at T2	-0.01	-0.17**	-0.03	0.00	0.12**	-0.07*	0.18**	-	-0.35**	-0.16**	0.32**	0.20**	0.30**	0.24**
9. Classroom antisocial behavior at T2	-0.08*	0.09*	0.06	-0.02	-0.03	0.05	-0.12**	-0.18**	-	-0.17**	-0.73**	-0.01	0.11**	0.01
10. Friends' support at T2	-0.06	-0.08*	-0.04	-0.09**	-0.12**	-0.07*	-0.11**	-0.14**	-0.31**	-	0.08*	0.03	0.04	0.06
11. Friends' antisocial behavior at T2	0.04	-0.18**	-0.08*	0.06	0.08*	-0.01	0.12**	0.09*	-0.30**	-0.03	-	0.04	0.09**	0.02
12. Antisocial behavior at T1	0.13**	-0.17**	-0.07*	0.12**	0.24**	-0.04	0.35**	0.25**	-0.12**	0.11**	0.03	-	0.49**	0.32**
13. Antisocial behavior at T2	0.07*	-0.13**	-0.10**	0.08*	0.12**	-0.05	0.29**	0.54**	-0.19**	0.01	0.10**	0.54**	-	0.52**
14. Antisocial behavior at T3	0.01	-0.19**	-0.13**	0.10**	0.16**	-0.01	0.29**	0.51**	-0.12**	0.03	0.06	0.51**	0.56**	-

* $p < .05$, ** $p < .01$

Table 4.3 *Effects of Resting Heart Rate and Peer Context on Adolescent Antisocial Behavior at T1*

	B (SE)			
	Step 1	Step 2	Step 1	Step 2
Intercept	0.196 (0.011)***	0.195 (0.011)***	0.254 (0.012)***	0.248 (0.012)***
Gender (1=boy; 0=girl)	0.204 (0.015)***	0.204 (0.015)***	0.089 (0.017)***	0.096 (0.017)***
Age (years) at T1	0.028 (0.008)***	0.028 (0.008)***	0.028 (0.007)***	0.028 (0.007)***
Family break-up at T1 (1=yes; 0=no)	0.047 (0.018)*	0.045 (0.018)*	0.036 (0.018)*	0.037 (0.018)*
Socio-economical status at T1 (SES)	-0.029 (0.008)***	-0.029 (0.008)***	-0.022 (0.008)**	-0.022 (0.008)**
Heart rate (beats per minute) at T1	-0.017 (0.008)*	-0.012 (0.010)	-0.011 (0.007)	-0.024 (0.011)*
Classroom emotional support at T1	0.008 (0.008)	0.008 (0.008)	-	-
Classroom bullying behavior at T1	0.049 (0.008)***	0.047 (0.008)***	-	-
Friends' emotional support at T1	-	-	-0.016 (0.008)*	-0.016 (0.008)*
Friends' bullying behavior at T1	-	-	0.107 (0.009)***	0.099 (0.009)***
Heart rate x Gender	-	-0.011 (0.015)	-	0.025 (0.018)
Heart rate x Emotional support	-	-0.006 (0.008)	-	0.003 (0.008)
Heart rate x Bullying behavior	-	-0.017 (0.008)*	-	-0.030 (0.009)**
R^2	15.4%	15.8%	20.3%	20.8%

* $p < .05$, ** $p < .01$, *** $p < .001$; *Note.* Interaction effects were calculated separately for classroom behavior and friends' behavior.

Table 4.4 *Effects of Resting Heart Rate and Peer Context on Adolescent Antisocial Behavior at T2*

	B (SE)			
	Step 1	Step 2	Step 1	Step 2
Intercept	0.255 (0.010)***	0.253 (0.010)***	0.255 (0.010)***	0.254 (0.010)***
Gender (1=boy; 0=girl)	0.030 (0.013)*	0.029 (0.013)*	0.024 (0.014)	0.023 (0.014)
Age (years) at T1	0.006 (0.006)	0.007 (0.006)	0.002 (0.006)	0.003 (0.006)
Family break-up at T1 (1=yes; 0=no)	0.053 (0.015)***	0.052 (0.015)**	0.064 (0.015)***	0.064 (0.015)***
Socio-economical status at T1	0.001 (0.006)	0.002 (0.006)	-0.005 (0.007)	-0.004 (0.007)
Antisocial behavior at T1	0.155 (0.007)***	0.155 (0.007)***	0.168 (0.007)***	0.168 (0.007)***
Heart rate (beats per minute) at T1	-0.008 (0.006)	0.005 (0.009)	-0.007 (0.006)	-0.003 (0.009)
Classroom support at T2	0.057 (0.007)***	0.057 (0.007)***	-	-
Classroom antisocial behavior at T2	-0.015 (0.006)*	-0.015 (0.006)*	-	-
Friends' support at T2	-	-	-0.006 (0.007)	0.003 (0.009)
Friends' antisocial behavior at T2	-	-	0.023 (0.006)***	0.022 (0.006)**
Heart rate x Gender	-	-0.026 (0.013)*	-	-0.022 (0.015)†
Heart rate x Peer support	-	-0.001 (0.007)	-	0.002 (0.007)
Heart rate x Peer antisocial behavior	-	0.008 (0.006)	-	-0.003 (0.007)
R^2	36.3%	36.6%	33.3%	33.4%

* $p < .05$, ** $p < .01$, *** $p < .001$; *Note.* Interaction effects were calculated separately for classroom behavior and friends' behavior.

4.5. Discussion

In the current study we hypothesized that there would be a person-environment interaction between biological underarousal and supportive and adverse peer contexts. Our findings were partly in line with this hypothesis; in a cross-sectional design we found that in adverse peer contexts characterized by more bullying behavior, low resting HR (as a biological marker of underarousal) was associated with more ASB in preadolescence. However, we found no support for a buffering role of supportive peer contexts. Second, prospectively we found that low resting HR predicted more ASB in adolescent boys while accounting for family and peer contexts and earlier levels of ASB. As expected, we did not find this effect in girls.

Our findings lend some support for the assumption that biological underarousal is only associated with negative outcomes in the presence of another risk factor (e.g., in classrooms where bullying behavior is highly prevalent; see also Dodge & Pettit, 2003). It is thus tempting to conclude that this finding provides an argument for including context in studies on the relationship between biological markers for underarousal and (antisocial) behavior. However, caution is warranted. In contrast to our second hypothesis, we found no evidence for a buffering effect of supportive peer contexts on ASB among subjects with low HR. Future research may aim to study other contexts that may have a buffering effect on the development of ASB, such as parenting behavior (e.g., Dekovic, 1999). Moreover, we only found an interaction effect with regard to adverse peer contexts in preadolescence and not in adolescence, which may be due to developmental differences. The interplay between biological factors and peer contexts may be especially relevant in preadolescence. In this period incidences of ASB are typically low compared to later adolescence (Agnew, 2003). That is, peer contexts characterized by ASB may deviate more from the behavioral norm and exert more influence on preadolescents. Especially for preadolescents with a heightened biological susceptibility to stimulation seeking, being in an adverse peer context could give rise to more ASB, as there are more opportunities for stimulation seeking and subsequently antisocial behaviors. In adolescence, however, ASB is more frequent and normative (Agnew, 2003; Moffitt, 1993), creating a lower threshold for behaving antisocially. As risky and antisocial behaviors increase in adolescence peer contexts may be similar in general with regard to adversity. As a result, biological underarousal may no longer be an important factor for peer influence with regard to individual ASB.

Related to our findings, future studies may also want to address the possibility of a differential biological susceptibility to context (Belsky & Pluess, 2009; Boyce & Ellis, 2005). Both the Biological Sensitivity to Context hypothesis (Boyce & Ellis, 2005; Obradovic & Boyce, 2009) and the Differential Susceptibility hypothesis (Belsky et al., 2007; Belsky & Pluess, 2009), suggest that some individuals are more susceptible to both negative and positive contextual circumstances than others. More specifically, a heightened biological susceptibility may be associated with adaptive outcomes in supportive environments, whereas it may lead to negative outcomes in adverse environments. Although this hypothesis is largely supported by studies

using markers of biological reactivity (Ellis et al., 2005; Obradovic et al., 2010), we argue that it may hold for underarousal of the autonomic nervous system marked by low resting HR as well. Individuals with low resting HR should be more inclined to seek out and engage in highly stimulating aspects of their environment, for better or for worse. Whereas we only found some supportive for the negative spectrum of this hypothesis, engaging in positive high-stimulation environments might also result in a more optimal physiological state (see e.g., Stadler et al., 2008).

Our findings need to be discussed in light of several limitations. First, we only assessed peer nominations and behavior within classrooms. However, there is evidence that peers outside school, from the neighborhood or sports club, also have a strong effect on individual ASB (Kiesner et al., 2003). Second, our peer nomination subsample had several constraints. Because peer nomination data were only collected in a subsample, we had to deal with missing data. We imputed these missing data using multiple imputations based on multiple background variables to overcome this bias (Royston, 2004). In addition, we did not have peer nominations at T3. Therefore we were not able to test whether peer context at T3 would still play an important role for the development of ASB of youth with low resting HR. As a suboptimal solution, we used peer nomination data obtained at T2 as a proxy for the peer context at T3, although we are aware that this peer context may have changed over time, at least to some extent.

Despite these limitations, the current study has two major strong points. The first strong point are the unique data obtained in a large general population sample which allowed us to test hypotheses on the effect of peer context on the relationship between resting HR and ASB. Although such a relationship has been suggested earlier (Scarpa & Raine, 2006), data constraints (i.e., both peer and physiological data are needed) did not make it possible to actually test such hypotheses. The second major strong point relates to the implications of our findings. Although this is to our knowledge the first study that has tested the interaction between resting HR and peer context, the current evidence is important for our view on the development of ASB. On the one hand, in preadolescence we showed that the association between low resting HR and ASB only surfaces in peer contexts characterized by high levels of bullying. In other words, the association between resting HR and ASB in preadolescence does not solely rest on one's biological make-up, but also depends upon the peer context. Interestingly, this interaction was present in both the classroom and more intimate (i.e., friendships) peer contexts. Moreover, although bullying behavior is distinct from ASB in general (Wolke et al., 2000), classroom and friends' bullying behavior can still affect levels of ASB in preadolescents with low resting HR. On the other hand, we showed that in boys the prospective relationship between resting HR and ASB exists over and above influences from the family and peer context. This suggests that there is a group of boys, characterized by low resting HR that is especially at risk for developing ASB irrespective of the context they are in.

Our prospective findings together with cross-sectional evidence from other studies (see Crozier et al., 2008; Rogeness et al., 1990), beg for a necessary side note regarding gender.

Namely, why does something biological, such as low resting HR, only *predicts* ASB in boys and not in girls? One possibility is that in girls, low resting HR is related to vulnerability to other (problematic) behaviors. It is tempting to speculate that whereas low resting HR in boys is more likely to lead to ASB, girls with low resting HR may be more inclined to display challenging prosocial behaviors (e.g., defending someone who is bullied). Future studies should test whether this explanation is feasible.

Overall, this study showed a cross-sectional person-environment interaction between resting HR and peer context, the truth may be less simple. Preadolescents and adolescents do not only get influenced by their peers but also select themselves into peer groups (e.g., Sijtsema et al., 2010a). That is, youth with low resting HR may be more inclined to hang out with antisocial peers who do more exciting things and in turn this may be associated with an increase in ASB. Future studies should examine this mediating moderation effect and try to tease apart these influence and selection effects.

Our prospective findings showed that peer contexts do not play a role in the relationship between HR and ASB. However, interventions may benefit from our findings in preadolescence. In preadolescence, efforts to improve classroom environment and monitoring children's friendship relations may thus pay off in terms of preventing the development of ASB in youth with low resting HR.