CHAPTER 4

TEMPERAMENTAL ACTIVATION AND INHIBITION IN ASSOCIATION WITH THE AUTONOMIC NERVOUS SYSTEM IN PREADOLESCENTS
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ABSTRACT

The aim of this study was to investigate temperamental activation (high-intensity pleasure) and inhibition (shyness) in relation to autonomic function as measured by heart rate (HR), respiratory sinus arrhythmia (RSA), and baroreflex sensitivity (BRS) in a preadolescent population cohort. Temperament was evaluated by parent-reports on the Revised Early Adolescent Temperament Questionnaire. Autonomic measurements were obtained in supine and standing position. Temperamental activation was negatively associated with supine HR and positively with supine RSA and BRS. Temperamental inhibition was positively related to supine BRS in girls only. Autonomic reactivity scores (i.e., difference between supine and standing) that were adjusted for supine values were unrelated to temperamental measures. Results suggest a physiological basis promoting the tendency towards engagement in activities with high intensities. Moreover, it appears that higher scores on the temperamental poles of activation (in both boys and girls) and inhibition (in girls only) are associated with increased dynamic and flexible autonomic regulation, which implicates healthy physiological functioning.
INTRODUCTION

Temperament refers to individual differences in overt behavior, emotion, and motivational styles. Differences in temperament are thought to have an underlying neurobiological basis (Strelau 1994). Especially the relationship between temperament and the autonomic nervous system has received considerable attention (Beauchaine 2001, Movius & Allen 2005). Often temperament is regarded as a feature of the early years of life. However, Rothbart & Derryberry (1981) use a more developmental framework of temperament in that it is shaped over time by an interplay between heredity, maturation, and experiences. This broadens the possibility of identifying temperament dimensions to include those that do not appear within the first years of life. In line with the model of Rothbart and Derryberry, in the present study we focused on the relationship between preadolescents’ temperament and autonomic function, a neglected research area so far.

Research in the field of temperament in association with autonomic function has traditionally focused on heart rate (HR), which reflects the balance between sympathetic and parasympathetic (vagal) activity. In addition, indices of vagal activity [such as heart rate variability (HRV) or respiratory sinus arrhythmia (RSA)] have become increasingly important as psychophysiological markers of emotion regulation and a wide range of other psychological variables (Beauchaine 2001, Bernston et al. 1997, Movius et al. 2005). Furthermore, recent studies have pointed to the potential value of baroreflex sensitivity (BRS) as a measure of autonomic function in relation to psychological variables (Virtanen et al. 2003, Watkins et al. 1999). BRS is an indicator of the quality of short-term blood pressure (BP) control, reflecting changes in inter-beat-intervals of HR due to changes in beat-to-beat BP (Ketch et al. 2002, Van Roon et al. 2004). Although BRS indicates both sympathetic and parasympathetic influences, BRS assessments at rest are likely to be mediated largely by vagal control (Pomeranz et al. 1985).

Two core dimensions of temperament may be distinguished: activation (approach) and inhibition (avoidance) (Elliot & Thrash 2002). Temperamental activation refers to an approaching and disinhibited behavioral style. Temperamental inhibition, on the other hand, comprises avoidant behaviors and withdrawal responses guided by feelings of anxiety (Gray 1991).

Despite some intriguing findings linking autonomic function with the two temperamental poles of activation and inhibition, this field of research has been characterized by inconsistent results. Here, we investigate the possible relationship of temperamental activation (high-intensity pleasure) and inhibition (shyness) with HR, RSA, and BRS in a large population cohort of preadolescents. We were specifically interested in high-intensity pleasure and shyness, as both factors have been shown to steer the conditional probability of either externalizing or internalizing problems, respectively, thus functioning as direction markers.
(Oldehinkel et al. 2004). We primarily focused on autonomic measures during supine rest. Additionally, we investigated autonomic reactions to orthostatic challenge (standing), as these have been shown to be related to psychological variables (Kagan et al. 1994, Mezzacappa et al. 1997, Yeragani et al. 1991) and are easily applicable in large-scale studies. Orthostatic challenge is known to lead to an increase of sympathetic activity and a decrease of parasympathetic activity, resulting in increased HR and decreased RSA and BRS.

We tested several hypotheses, generated by previous studies, but also explored possible temperament-autonomic nervous system relationships that had received little research attention so far. First, we investigated if individuals with higher scores on temperamental activation had lower HR. Stimulation-seeking theory states that low arousal levels are physiologically unpleasant and may lead to engagement in exciting behaviors that increment the low arousal level to an optimal or normal level (Eysenck 1997). While an association between temperamental activation and low HR has indeed been shown in a few studies in infants and young children (Raine 1996, Raine et al. 1997, Zuckerman 1990), surprisingly, the most recent studies (in adults) have suggested no association between temperamental activation and HR (Heponiemi et al. 2004, Keltikangas-Jarvinen 1999, Knyazev et al. 2002).

The second hypothesis we tested was whether behaviorally inhibited preadolescents would show a higher HR, as had been demonstrated in young children in the pioneering work of Kagan and colleagues (Garcia Coll et al. 1984, Kagan et al. 1987, Kagan et al. 1988). They argued that autonomic overarousal (as reflected in higher HR) may be characteristic of individuals who are prone to extreme fearfulness and withdrawal from unfamiliar situations (Kagan et al. 1994). A number of other studies have also reported an increased HR in inhibited three-year-old children (Scarpa et al. 1997) and anxious adolescent boys (Mezzacappa et al. 1997). However, not all available studies in children and adults have uniformly replicated Kagan’s findings (Calkins & Fox 1992, Heponiemi et al. 2004, Knyazev et al. 2002, Marshall & Stevenson-Hinde 1998, Schmidt et al. 1999). Thus, the literature on the relationship between temperamental inhibition and HR is inconclusive and in need of further investigation (Fox et al. 2005, Marshall & Stevenson-Hinde 2001).

Furthermore, we aimed to explore whether temperamental activation and inhibition would be linked with, respectively, increased and decreased vagal activity (as indexed by supine RSA and BRS). Increased vagal activity is thought to promote physiological flexibility and adaptability to meet environmental demands (Porges 1995, Porges et al. 1996), and may also be associated with increased openness to new experiences and temperamental reactivity (Beauchaine 2001, Porges et al. 1994). Higher baseline RSA levels have indeed been suggested in infants and children with a high tendency to approach (Beauchaine 2001, Richards & Cameron 1989), but this has never been investigated in preadolescents.

In contrast to temperamental activation, early studies have suggested lower vagal tone in inhibited young children (Garcia Coll et al. 1984; Reznick et al. 1986),

Recently, some studies have suggested that BRS may be a more sensitive measure of autonomic function than RSA. Interestingly, anxiety and hostility were more closely (inversely) associated with BRS than with RSA in those studies (Virtanen et al. 2003, Watkins et al. 1998, Watkins et al. 1999). To date, only very few studies are available linking BRS with psychological variables, especially in children. Some researchers have demonstrated an inverse relationship between BRS and pathological or non-pathological anxiety in adults (Virtanen et al. 2003, Watkins et al. 1998, Watkins et al. 1999). We know of only one study on the relationship between BRS and behavioral activation, in which a lower BRS was found for impulsive boys, but not girls (Allen et al. 2000).

Taken together, the reviewed literature shows inconsistent and equivocal results regarding the relationship between temperament and autonomic function, with a lack of research in preadolescents. The aim of the present study was to investigate the relationship between temperament and autonomic function in a large preadolescent population as part of an ongoing cohort study. HR, RSA, and BRS in the supine and standing position were included as measures of autonomic function. High-intensity pleasure (i.e., stimulation-seeking) was selected as a measure of temperamental activation and shyness as a measure of temperamental inhibition. We expected different autonomic patterns to be associated with temperamental activation and inhibition.

**METHOD**

**Participants**

This study was performed in 938 10-to-13-year-old Dutch preadolescents (442 boys, mean 11.6 yrs, SD 0.5, 93% Caucasian) who all participate in the ongoing longitudinal community-study “TRacking Adolescents’ Individual Lives Survey” (TRAILS) (De Winter et al. 2005). The key objective of TRAILS is to chart and explain the development of mental health from preadolescence into adulthood, both at the level of psychopathology and the levels of underlying vulnerability and environmental risk. Sample selection procedures and methods of TRAILS have recently been described (De Winter et al., 2005). In the present TRAILS subsample, we included all preadolescents for whom parent-reported temperament scores and reliable BRS values in both the supine and standing position were available.
The mean body mass index in the current sample was 18.9+/-3.1 kg/m². About 12.5% of the participants (almost) never engage in physical activities, 24.5% once a week, 34.8% 2-3 times a week, and 14% 4-7 times a week. Drinking alcohol on a regular basis has been reported by 0.6% of the participants, sometimes or a little bit by 5.7%, and (almost) never by 93.7%. Smoking tobacco regularly has been reported by 0.2%, sometimes or a little bit by 2%, and (almost) never by 97.8%. A more detailed description of the study population that participated in the cardiovascular measurements has been described in our previous studies (Dietrich et al. 2006). Written informed consent was obtained from the preadolescents’ parents. The study was approved by the National Dutch Medical Ethics Committee.

**Measurements**

**Temperament**

Temperament was assessed by parents’ responses on the Early Adolescent Temperament Questionnaire (EATQ-R) (Hartman 2000, Putnam et al. 2001). We included only those subscales of the EATQ-R that reflect temperamental activation and inhibition. Those subscales were high-intensity pleasure (i.e., parents indicated how much pleasure their child would derive from activities involving high intensity or novelty, such as deep sea diving and mountain climbing; 6 items, Cronbach’s alpha 0.77) and shyness (i.e., behavioral inhibition to novelty and challenge, especially social; 4 items, Cronbach’s alpha 0.84), measured on a 5-point scale. The factor structure and internal consistency of the EATQ-R scales have been verified empirically in the TRAILS cohort (Oldehinkel et al. 2004). The parent version of the EATQ-R was used because the factor structure has proved to be superior compared to the child version (Oldehinkel et al. 2004). Table 1 shows gender-specific means and standard deviations of the temperament scales.

<table>
<thead>
<tr>
<th>Boys (N=442)</th>
<th>Girls (N=496)</th>
<th>Boys versus Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Intensity Pleasure</td>
<td>3.4 (0.9)</td>
<td>3.2 (0.9)</td>
</tr>
<tr>
<td>Shyness</td>
<td>2.4 (0.9)</td>
<td>2.6 (0.9)</td>
</tr>
</tbody>
</table>

**Notes:** Gender differences by Student’s t-tests.
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Cardiovascular variables
Cardiovascular measurements took place individually in a quiet room at school. Spontaneous fluctuations in continuous beat-to-beat systolic finger BP were measured non-invasively by the Portapres device. HR was registered by a three-lead electrocardiogram. Recordings did not start after a few minutes of supine rest and only after signals reached a stabilized steady-state after circulatory readjustments of body fluid changes. Then, BP and HR signals were registered for 4 minutes in the supine position during spontaneous breathing, followed by 2 minutes in the standing position, again after signals had stabilized.

Calculation of RSA and BRS was performed by spectral analysis using the transfer function technique as described previously (Dietrich et al. 2006, Robbe et al. 1987). The CARSPAN software program allows for discrete Fourier transformation of non-equidistant systolic BP and interbeat-interval-series. The analyzed time series were corrected for artifacts and checked for stationarity. RSA was defined as the high-frequency power (ms$^2$) in the 0.15-0.40 Hz respiratory band. RSA is associated with the rhythmic fluctuations in HR caused by respiration and is an index of vagal activity (Berntson et al. 1997). BRS was defined as the mean modulus between systolic BP and interbeat-interval-series in the 0.07-0.14 Hz frequency band (ms/mmHg) with a coherence of more than 0.3. We have previously shown that use of coherence levels of 0.3 and 0.5 yield highly similar BRS values (Dietrich et al. 2006). A more detailed description of the cardiovascular data assessment, analysis, and variables is given by Dietrich et al. (2006).

Statistical analysis
RSA and BRS values were transformed to a normal distribution by taking their natural logarithm before analyzing them statistically. In addition, the temperament measures were transformed to a standard normal distribution (z-scores). Pearson’s correlation coefficients were calculated to determine correlations between the cardiovascular measures.

To examine the effects of temperament on autonomic function, univariate and repeated-measures variance analyses (ANOVA’s) were performed for each cardiovascular variable (HR, RSA, BRS) separately, using respectively supine and both supine and standing cardiovascular measures as continuous dependent variables. Thus, difference scores between autonomic variables in supine and standing position (i.e., standing-induced autonomic reactivity) were actually calculated by repeated-measures ANOVA and used as dependent variables. Given the correlation between temperamental activation and inhibition ($r=-.29$), both temperament scales were entered as continuous independent variables into the model, and were thus adjusted for each other. Also, gender was included as an independent variable in the model, given the association with both temperament and cardiovascular measures (Dietrich et al. 2006, Oldehinkel et al. 2004). Additionally, two-way interactions between gender and temperament (gender*activation and gender*inhibition) were
added, as literature suggested gender differences in the relation between psychological variables and autonomic function (Beauchaine 2001). We additionally explored temperamental activation-inhibition interactions, as both factors may augment or attenuate each other. When analyzing autonomic reactivity scores, we adjusted for baseline (supine) cardiovascular levels by including supine levels as independent covariates, in accordance with the law of initial values (Benjamin 1963). To further analyze significant gender-interactions, we repeated analyses stratified for gender.

Previous analyses in the present study sample had not revealed associations between cardiovascular variables (HR, RSA, BRS) and body mass index, pubertal stage, physical activity level, alcohol and tobacco consumption, and socio-economic status (see also Dietrich et al. 2006). Hence, these factors were not considered as covariates in the present analyses. For the purpose of presentation of the continuous temperament scores, three groups of preadolescents with low (<1SD below mean), moderate (values >1SD below and <1SD above mean), and high (>1SD above mean) scores were composed (see figures). Mean values of the three groups were based on ANOVA’s and thus adjusted for covariates. P-values smaller than 0.05 were considered statistically significant. Values have been given as mean+/−SD, unless otherwise stated.

RESULTS

Cardiovascular variables and Gender effects

Table 2 presents gender-specific means and standard deviations of HR, RSA, and BRS measured in the supine and standing position. HR was significantly higher in the standing than in the supine position ($F_{1,933} = 3006.4$, $p < .001$, $\eta^2 = .763$), whereas RSA ($F_{1,933} = 1265.7$, $p < .001$, $\eta^2 = .576$) and BRS ($F_{1,933} = 739.5$, $p < .001$, $\eta^2 = .442$) were significantly lower. Girls had higher supine HR values ($F_{1,933} = 19.3$, $p < .001$, $\eta^2 = .020$), but lower supine RSA ($F_{1,933} = 10.0$, $p = .002$, $\eta^2 = .011$) and supine BRS values ($F_{1,933} = 17.2$, $p < .001$, $\eta^2 = .018$) than boys. There was no gender effect regarding HR, RSA, and BRS reactivity.

RSA was positively correlated with BRS in both the supine ($r = .65$, $p < .001$) and standing position ($r = .71$, $p < .001$). HR was inversely related to RSA and BRS, also in both the supine (RSA: $r = -.63$, $p < .001$; BRS: $r = -.52$, $p < .001$) and standing position (RSA: $r = -.70$, $p < .001$; BRS: $r = -.67$, $p < .001$). Furthermore, subjects with higher supine HR displayed lower HR reactivity ($r = -.13$, $p < .001$), whereas those with higher supine RSA and supine BRS showed increased RSA reactivity (i.e., greater suppression of RSA, $r = .48$, $p < .001$) and BRS reactivity ($r = .56$, $p < .001$), respectively.
Table 2. Gender-specific means and standard deviations of the cardiovascular variables.

<table>
<thead>
<tr>
<th></th>
<th>Supine position</th>
<th>Standing position</th>
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<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Boys (N=442)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>75.9 (10.5)</td>
<td>92.9 (13.5)</td>
</tr>
<tr>
<td>RSA ln(ms^2)</td>
<td>7.5 (1.3)</td>
<td>6.0 (1.3)</td>
</tr>
<tr>
<td>BRS (ms/mmHg)</td>
<td>16.4 (9.4)</td>
<td>9.5 (5.3)</td>
</tr>
<tr>
<td>BRS ln(ms/mmHg)</td>
<td>2.6 (0.6)</td>
<td>2.1 (0.6)</td>
</tr>
<tr>
<td>Girls (N=496)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>79.3 (11.3)</td>
<td>95.6 (13.4)</td>
</tr>
<tr>
<td>RSA ln(ms^2)</td>
<td>7.2 (1.3)</td>
<td>5.9 (1.2)</td>
</tr>
<tr>
<td>BRS (ms/mmHg)</td>
<td>14.1 (8.7)</td>
<td>8.4 (4.4)</td>
</tr>
<tr>
<td>BRS ln(ms/mmHg)</td>
<td>2.5 (0.6)</td>
<td>2.0 (0.5)</td>
</tr>
</tbody>
</table>

Notes: HR=heart rate; RSA=respiratory sinus arrhythmia power in the 0.15-0.40 Hz high-frequency band; BRS=baroreflex sensitivity (modulus in the 0.07-0.14 Hz low-frequency band); ln=natural logarithm. Supine versus standing based on t-tests: all significant at p<.001; boys versus girls: supine all significant at p<.001; standing: HR and BRS significant at p<.01.

Temperament and autonomic function

Temperamental activation

Supine. Temperamental activation was negatively associated with HR ($F_{1,933}=12.7$, $p<.001$, $\eta^2=.014$; Figure 1), and positively with RSA ($F_{1,933}=7.7$, $p=.006$, $\eta^2=.008$; Figure 2) and BRS ($F_{1,933}=6.4$, $p=.012$, $\eta^2=.007$; Figure 3).

Reactivity. There was no relationship between temperamental activation and HR reactivity ($F_{1,932}=0.5$, $p=.465$, $\eta^2=.001$), RSA reactivity ($F_{1,932}=0.5$, $p=.481$, $\eta^2=.001$), and BRS reactivity ($F_{1,932}=0.2$, $p=.636$, $\eta^2=.001$).

Temperamental inhibition

Supine. Temperamental inhibition was not related to HR ($F_{1,933}=0.1$, $p=.857$, $\eta^2=.001$) and RSA ($F_{1,933}=0.8$, $p=.370$, $\eta^2=.001$), but there was a significant gender-interaction between Temperamental inhibition and BRS ($F_{1,933}=4.6$, $p=.032$, $\eta^2=.005$). Subsequent gender-stratification showed a significant positive relationship between temperamental inhibition and BRS in girls ($F_{1,492}=9.6$, $p=.002$, $\eta^2=.019$) (Figure 4), but not in boys ($F_{1,438}=0.1$, $p=.956$, $\eta^2=.001$).

Reactivity. Temperamental inhibition was not related to HR reactivity ($F_{1,932}=0.8$, $p=.379$, $\eta^2=.001$), RSA reactivity ($F_{1,932}=2.4$, $p=.122$, $\eta^2=.003$), nor BRS reactivity ($F_{1,932}=0.2$, $p=.627$, $\eta^2=.001$).
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Figure 1. Temperamental activation (high-intensity pleasure) versus supine heart rate (HR). To visualize the continuous temperament scores, three groups of preadolescents with low (<1SD below mean), moderate (values >1SD below and <1SD above mean), and high (>1SD above mean) scores were composed. The mean scores were adjusted for covariates. Error bars represent SE.

Figure 2. Temperamental activation (high-intensity pleasure) versus supine respiratory sinus arrhythmia (RSA). Descriptions as in figure 1.
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Figure 3. Temperamental activation (high-intensity pleasure) versus supine baroreflex sensitivity (BRS). Descriptions as in figure 1.

Figure 4. Temperamental inhibition (shyness) versus supine baroreflex sensitivity (BRS) in girls. Descriptions as in figure 1.
DISCUSSION

We studied the relationship between the two temperamental poles of activation (high-intensity pleasure) and inhibition (shyness) and autonomic function, as measured by HR, RSA, and BRS in preadolescents from a large population cohort. In contrast to our expectations, we did not find clearly different autonomic patterns to be associated with temperamental activation versus inhibition. Both temperamental dimensions appeared to have a link with increased dynamic autonomic regulation as reflected in increased RSA and BRS (temperamental inhibition in girls only). Moreover, temperamental activation was associated with autonomic underarousal as indicated by lower HR.

It appeared that basal autonomic reactions to orthostatic challenge when adjusted for supine levels were not related to temperamental activation and inhibition, despite earlier reports suggesting a relationship between orthostatic stress and psychological variables (e.g., inhibition, depression, antisocial behavior) (Kagan et al. 1994, Mezzacappa et al. 1997, Yeragani et al. 1991). Apparently, the present physiological stressor did not evoke autonomic responses in higher brain structures (e.g., amygdala), which are thought to be involved in emotion and behavior regulation, in contrast to psychological stressors (Kagan et al. 1988, Schwartz et al. 2003). Rather, orthostatic challenge has been shown to engage predominantly brain stem systems and to trigger a basal, reflexive autonomic reaction (Berntson et al. 2004).

Our finding of a lower supine HR in relation to temperamental activation appeared to largely result from increased vagal activation, given the high correlation between HR and RSA ($r=-.63$) in the present sample, but may also partially be explained by decreased sympathetic activity (which was not measured in our study).

The finding of a lower HR fits with the concept of autonomic underarousal associated with a stimulation-seeking trait (Raine 1996, Zuckerman 1990). States of autonomic underarousal are thought to be physiologically unpleasant and to lead to engagement in sensation-evoking behaviors in order to counterbalance the low levels of arousal (Raine 2002). Thus, HR does not only appear to be decreased in association with externalizing psychopathology (Ortiz & Raine 2004), but also with a stimulation-seeking temperament, which is thought to underlie externalizing behavior (Raine et al. 1998).

A lower HR in relation to temperamental activation had previously been reported in infants and children (Raine 2002, Scarpa et al. 1997, Zuckerman 1990) but not in adults (Heponiemi et al. 2004, Knyazev et al. 2002). The present results indicate that an association between HR and stimulation-seeking is also present in preadolescents.

Temperamental activation not only appeared to be positively associated with RSA, a well-established measure of vagal functioning, but also with BRS, in both boys and girls. Supine RSA and BRS were highly correlated ($r=.65$), reflecting the
largely, although not exclusively, vagal role of the baroreflex. Vagal activity supports restoration of health following threats or challenges (Porges et al. 1996). Porges et al. (1995, 1996) pointed to the regulatory function of parasympathetic activity serving as a vagal “brake” to promote physiological flexibility and adaptability to meet environmental demands. This may also be manifested in increased openness to new experiences and behavioral and emotional responsivity (Porges et al. 1994). The present findings point to increased dynamic and flexible autonomic regulation (Beauchaine 2001, Thayer & Brosschot 2005) and are in line with earlier reports linking increased vagal activity to a greater capacity for active engagement with the environment (Beauchaine 2001, Movius et al. 2005).

Unexpectedly, neither HR nor RSA were related to temperamental inhibition in the present large preadolescent population cohort. Developmental changes in the maturation of the autonomic system and differentiation of temperament characteristics may play a role. Indeed, most studies that have reported increased HR and decreased RSA in relation to temperamental inhibition were conducted in infants and young children (Garcia Coll et al. 1984, Kagan et al. 1987, Reznick et al. 1986, Scarpa et al. 1997), whereas studies that did not find a relationship between these measures and inhibition concerned mostly older children and adults (Brenner 2005, Heponiemi et al. 2004, Hofmann et al. 2005, Marshall et al. 1998, Knyazev et al. 2002, Schmidt et al. 1999). These findings stress that HR and RSA may be related to inhibition primarily in infants and young children (Marshall et al. 2001).

Interestingly, in our study, in girls BRS was positively associated with temperamental inhibition, whereas RSA was unrelated to it. While we can only speculate about reasons for this, we suspect that BRS (reflecting reflexive autonomic regulation) more sensitively reflects the balance between parasympathetic and sympathetic autonomic activity than does RSA (reflecting tonic autonomic control). Thus, our results further support the idea that BRS may be a sensitive and valuable measure of autonomic function in relation to psychological variables, as had been suggested previously (Virtanen et al. 2003).

We know of one other study which reported a non-significant positive association between inhibition and vagal tone in men (Movius et al. 2005). The few studies in adults that have previously investigated the association between BRS and inhibition (i.e., pathological or trait anxiety), all have reported reduced as opposed to increased BRS values (Virtanen et al. 2003, Watkins et al. 1998, Watkins et al. 1999). Adult samples (Virtanen et al. 2003, Watkins et al. 1998) may differ from children or adolescents in that third variables that are associated with inhibition (e.g., anxiety) may have influenced cardiovascular functioning during the life course, such as high blood pressure (or cardiovascular disease), alcohol and tobacco use, emotional illnesses like depression, which have all been related to decreased vagal functioning (see also Thayer et al. 2005). However, studies with infants and young children have also found lowered vagal function in association with inhibition (Garcia Coll et al. 1984, Reznick et al. 1986).
Conclusions

In summary, this study points to a direct, albeit weak, association between temperamental activation (high-intensity pleasure) and lower HR in preadolescent boys and girls from a large population cohort. Moreover, temperamental activation was associated with increased RSA and BRS, pointing to increased vagal control of HR and better BP regulation. This increased autonomic regulation, which is expressed through variability in the dynamic and flexible relationship among system elements, has been associated with healthy (psychological and physiological) processes (Beauchaine 2001, Thayer et al. 2005). This autonomic profile may also promote the tendency towards engagement in activities with high intensities.

In addition, girls’ temperamental inhibition (shyness) was also linked to increased autonomic regulation as indicated by BRS, possibly suggesting that, at least in preadolescent girls, shyness may be a physiologically adaptive trait. It thus appears that higher scores on the temperamental poles of activation (in both boys and girls) and inhibition (in girls only) are associated with increased autonomic regulation. It should be noted, however, that the effect sizes were small, which may be partly explained by the less than perfect and variable measurement conditions as a consequence of the assessments at schools. Future studies are needed that shed more light on the relationship between autonomic function and temperament (inhibition, in particular), preferably at different points in the development. Overall, the results might indicate that individual differences in autonomic function play some role in individual differences in overt behavior, emotion, and motivation.
REFERENCES


