EXTERNALIZING AND INTERNALIZING PROBLEMS IN RELATION TO AUTONOMIC FUNCTION: A POPULATION-BASED STUDY IN PREADOLESCENTS
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ABSTRACT

Objective: To investigate whether externalizing and internalizing problems are related to lower and higher heart rate (HR), respectively, and to explore the relationship of these problems with respiratory sinus arrhythmia (RSA) and baroreflex sensitivity (BRS). Moreover, to study whether problems present at both preschool and preadolescent age show stronger associations with autonomic function than those that were not. Method: In a population cohort of 10-to-13-year-old children (N=931; 11.6+/-0.5 yrs; 47% boys), autonomic measurements in supine and standing position were performed at school. RSA and BRS were determined by spectral analysis. Current externalizing and internalizing problems were assessed by the Child Behavior Checklist and problems at age 4-5 retrospectively by the Preschool Behavior Questionnaire. Results: At supine rest, current externalizing problems were associated with lower HR and higher RSA, but not with BRS; current internalizing problems with higher HR and lower RSA, but not with BRS. These results were specifically found in children with problems that were retrospectively reported to have been also present at preschool age. Standing-induced changes in autonomic parameters were unrelated to the behavioral dimensions. Conclusions: Externalizing and internalizing problems are associated with divergent autonomic patterns, suggesting autonomic underarousal and overarousal, respectively. Problems starting early in life might specifically account for this. This should be confirmed in prospective studies.
INTRODUCTION

An extensive literature suggests an association between both externalizing and internalizing psychopathology and autonomic nervous system function in adults as well as in children (Beauchaine 2001, Lorber 2004, Ortiz & Raine 2004). One of the best-replicated biological correlates of child psychopathology is a lower resting heart rate (HR) in children with externalizing problems (Lorber 2004, Ortiz & Raine 2004). This association has often been explained by theories of autonomic underarousal or fearlessness leading to sensation-seeking and disruptive behaviors (Ortiz & Raine 2004, Raine 1993).

The relationship of resting HR with internalizing problems in children is less clear. Kagan et al. (1994) argued that increased autonomic activity (overarousal) may be characteristic of children who are prone to extreme fearfulness and withdrawal from unfamiliar situations, which is a risk factor for developing anxiety symptoms (Kagan & Snidman 1999). Indeed, the few available and often small-sized studies mostly reported increased resting HR in children with internalizing problems (Kagan et al. 1987, Kagan et al. 1988, Monk et al. 2001, Scarpa et al. 1997), although not universally so (Dorn et al., 2003, Pine et al. 1998).

HR reflects the balance between activity of the two main branches of the autonomic nervous system, the sympathetic and parasympathetic (vagal) divisions. Sympathetic activation aims to mobilize bodily resources to cope with threats or challenges. Parasympathetic influences promote restoration of health following threats or challenges, and are primarily associated with calm states. In resting states, HR is largely mediated by vagal tone, which functions to slow down HR (Jose 1966). Thus, in general, there is an inverse relationship between HR and vagal activity (Beauchaine 2001, Berntson et al. 1993).

Respiratory sinus arrhythmia (RSA), a measure of the magnitude of rhythmic fluctuations in HR caused by respiration, is the preferred indicator of vagal activity (Beauchaine 2001, Berntson et al. 1993). Thus, high RSA is a marker of increased vagal tone. Baroreflex sensitivity (BRS), in contrast, is an integrated measure of both sympathetic and vagal activity. The baroreflex is a short-term blood pressure (BP) control mechanism; BRS reflects changes in beat-to-beat HR resulting from variations in BP. A reduced BRS is a well-known indicator of autonomic dysfunction.

The relationship between vagal function and both externalizing and internalizing problems is still understudied and unclear (Lorber 2004, Scarpa & Raine 2004). Given the inverse relationship between HR and vagal activity and the association between lower HR and externalizing psychopathology, higher vagal activity would be expected in children with externalizing problems (Scarpa & Raine 2004), whereas in those with internalizing problems lower vagal activity would be expected as an explanation for their higher HR. Some studies found indeed a link between externalizing problems and increased vagal activity in children and adults (Cole et al. 1996, Scarpa & Ollendick 2003, Van Voorhees & Scarpa 2002), and

Furthermore, studies investigating BRS in relation to externalizing and internalizing problems are lacking in children. In adults, a reduced BRS has been associated with depression and anxiety (Broadley et al. 2005, Virtanen et al. 2003). However, we know of only one study regarding the relationship between BRS and psychopathology in children, in which reduced BRS was linked to externalizing behavior (impulsiveness) in boys, but not in girls (Allen et al. 2000).

Thus, despite a number of intriguing findings in favor of an association between behavior profiles and autonomic function, this field of research is still characterized by inconsistent and sometimes conflicting results. These inconsistencies may be explained by the use of mostly moderately-sized study samples and specific study populations (e.g., males only, or high-risk populations), thereby limiting generalizability of results.

Autonomic reactions induced by orthostatic challenge have also been reported to be related to behavioral and emotional problems (Mezzacappa et al. 1997, Yeragani et al. 1991). Compared to psychological stressors, orthostatic stress may have the advantage of reducing confounding influences in terms of anticipatory anxiety (Stein et al. 1992), and of being independent from the participant’s motivation, attention, and intellectual abilities. Therefore, we hypothesized that this basic, reflexive physical stressor could be a viable alternative to commonly used psychological stressors (such as public speaking or cognitive tests), the use of which is limited in large study samples for practical reasons.

The primary goal of the current study was to examine the relationship between different autonomic indices (HR, RSA, BRS) and both externalizing (i.e., aggression, delinquency) and internalizing problems (i.e., anxiety, depression, somatic complaints), by using a large preadolescent community sample as part of an ongoing cohort study. As a secondary goal, we explored the validity of using autonomic nervous system reactions to orthostatic challenge (i.e., standing) as a marker of psychopathology.

Our epidemiological design enabled us to determine the relevance of autonomic parameters in the general population, given the high statistical power associated with large samples and the possibility to study gender differences (Bauer et al. 2002, Fox et al. 2005). We were specifically interested in whether we could find a lower HR in children with externalizing problems and a higher HR in children with internalizing problems. Also, we examined whether both types of problem dimensions would be associated with an altered RSA and BRS, which had been understudied so far.

Finally, we preliminarily investigated the possible relevance of problems that started early in life (based on retrospective report) in relation to autonomic function.
It might be argued that children with problems that begin early in life form an etiologically distinct group with specific biological features (Kagan & Snidman 1999). We expected that children with early starting problems would show stronger associations with autonomic indices than children without a history of early problems.

**METHOD**

**Participants**

This study included 931 10-to-13-year-old Dutch children (47% boys; 11.6+/-.05 yrs, 93% Caucasian) who took part in the baseline assessment of the longitudinal cohort “TRacking Adolescents’ Individual Lives Survey” (TRAILS; total N=2,230). Using biennial assessments, TRAILS investigates the development of mental health from preadolescence into adulthood (until age 24), both at the level of psychopathology and the levels of underlying vulnerability and environmental risk.

Participants were recruited through written invitations to parents and children of the required age range from five municipalities in the north of The Netherlands, including both urban and rural areas. Children from schools for special education within our catchment area were part of the study; however, children with mental retardation were excluded. A more detailed description of the sample selection procedures and sample characteristics of TRAILS has been given by de Winter et al. (2005).

A subgroup of 1,868 (84%) from the 2,230 children participated in the autonomic measurements; not all children have been included, mainly because autonomic measurements started a few months after the TRAILS data collection had begun. This also explains why the present subsample is slightly older (11.6+/-.05 yrs) than the general TRAILS sample (11.1+/-.06 years; t=38.6, p<.001). The 1,868 autonomic measurements were checked according to quality criteria, resulting in 1,472 reliable supine and 1,129 reliable standing measurements that met our quality standards (described in detail by Dietrich et al. 2006). We included only children of whom reliable autonomic values in both the supine and standing positions (n=1027) as well as behavioral scores (931 out of these 1027) were available, to avoid bias due to differences in group sizes. Behavioral scores were missing when, for unknown reasons, parents did not return the survey. The present subsample (n=931) does not differ from the general TRAILS sample (n=2,230) regarding gender, body mass index (BMI), pubertal stage, and externalizing and internalizing problems.

The mean BMI in the current sample was 18.9+/-.3.1 kg/m²; 31.0% of the participants were in Tanner stage 1 (preadolescence), 55.2% in stage 2 (early adolescence), 13.5% in stage 3 (middle adolescence), and 0.3% in stage 4 (late adolescence) (Tanner 1962). A more detailed description of the study population...
that participated in the autonomic measurements has been reported elsewhere (Dietrich et al. 2006).

Written informed consent was obtained from the children’s parents. All children voluntarily participated in the measurements, although no formal assent procedure has been followed for children. The study was approved by the National Dutch Medical Ethics Committee.

**Measures and Procedure**

**Externalizing and internalizing problems**

Children’s current externalizing and internalizing problems were based on their parents’ responses to Child Behavior Checklist (CBCL/6-18; Achenbach & Rescorla 2001). The CBCL allows for the determination of an externalizing (subscales ‘aggression’ and ‘delinquency’) and internalizing (subscales ‘anxious/depressed’, ‘withdrawn/depressed’, and ‘somatic complaints’) dimension. We used only parent-based ratings for two reasons. First, we judged that the subjects’ preadolescent age would make them a less reliable source of information than their parents. Second, we aimed to compare subgroups of children with and without early problems, for which we had to rely on retrospective parent reports.

Children’s externalizing and internalizing behavior at age 4 to 5 was assessed retrospectively by their parents, who compared their child’s behavior with that of other children (which we thought would more readily facilitate detection of behavioral deviations) on a 5-point Likert scale using the TRAILS Preschool Behavior Questionnaire (TPBQ). The TPBQ is non-validated, but was used given the lack of validated instruments that retrospectively assess children’s preschool behavior. The TPBQ externalizing subscale has 4 items (Cronbach’s alpha 0.70) assessing whether the child was ill-tempered, disobedient, bossy, and bullying, respectively. The internalizing subscale has 7 items (Cronbach’s alpha 0.80), on obsessive-compulsive behaviors, sadness, general anxiety, school anxiety, being bullied by other children, shyness, and being avoided by other children, respectively. Mean scores were computed for each CBCL and TPBQ problem dimension.

**Autonomic parameters**

Autonomic measurements were performed individually in a quiet room at school, generally in the morning (8.30 am-noon) and occasionally in the early afternoon (1.00-3.00 pm). 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 had 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 power spectral analysis using the transfer function technique as previously described (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 (IBI)-series. IBI refers to the time between two heart beats. 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. BRS was defined as the mean modulus between systolic BP and IBI in the 0.07-0.14 Hz frequency band (ms/mmHg) with a coherence of more than 0.3. We have previously shown that coherence levels of 0.3 and 0.5 yield highly similar BRS values (Dietrich et al. 2006).

A more detailed description of the autonomic data assessment, analysis, and variables has been reported in our previous study (Dietrich et al. 2006).

**Statistical analysis**

To approximate a normal distribution, RSA and BRS values were transformed to their natural logarithm, and the TPBQ and CBCL scores to z-scores. Relationships between the autonomic variables were investigated by Pearson’s correlation coefficients. We performed two subsequent sets of analyses: (1) to study current externalizing and internalizing problems in relation to autonomic function, we used continuous CBCL scores, thus, without regarding preschool scores (TPBQ), and (2) to investigate the role of early starting problems, we compared three groups of children with either externalizing or internalizing problems, which were or were not present at preschool or preadolescent age. The groups were based on the median split of TPBQ and CBCL scores and described as 1. early starters (TPBQ>P50 and CBCL>P50), 2. current-only (TPBQ<P50 and CBCL>P50), and 3. controls (TPBQ<P50 and CBCL<P50). A fourth group with preschool but not current problems (TPBQ>P50 and CBCL<P50) was not included in the analyses, since we primarily aimed to investigate whether possible relationships between current CBCL problems and autonomic function could be specifically found in children with problems that were already present at preschool age, rather than to study the role of early problems per se.

We used analyses of variance (ANOVA’s) for the two sets of analyses as described above. To analyze autonomic measures in the supine resting position, we conducted separate univariate ANOVA’s with each autonomic measure (HR, RSA, BRS) as the dependent variable, and gender, age, CBCL or TPBQ externalizing and internalizing problems, and gender-behavior-interactions as independent variables. By including both externalizing and internalizing problems, we adjusted for the influence of the other, given the correlations between both dimensions in our sample (TPBQ: Pearson’s \( r = .28 \); CBCL: Pearson’s \( r = .48 \)). In case of a significant gender-behavior-interaction, we repeated the analyses stratified for gender. Bonferroni post-hoc corrections for multiple comparisons were applied.

To analyze standing-induced autonomic reactivity scores (i.e., difference between supine and standing), we performed separate repeated-measures ANOVA’s for each autonomic measure in both the supine and standing positions (HR, RSA, BRS) as the dependent variables (thus, difference scores between
autonomic variables in supine and standing position were calculated within repeated-measures ANOVA). In accordance with the law of initial values (Benjamin, 1963), we adjusted for baseline (supine) autonomic levels by including them as covariates. We applied the same procedure regarding the independent variables as described above.

Exploratory analyses (correlational and multivariate) in this study sample did not reveal associations between autonomic variables and potential confounders, including BMI, pubertal stage, physical activity level, alcohol and tobacco consumption, socio-economic status, and physical health problems (i.e., diabetes mellitus, anemia, eczema, acne, and sinusitis), with the exception of allergies and asthma or bronchitis (see also Dietrich et al., 2006). Moreover, the results of this study remained unchanged after adjusting for these potential confounders in multivariate analyses. Hence, these factors were not considered further in this study.

As a measure of strength of associations, we reported partial $\eta^2$, which is comparable to $r^2$, expressing the percentage explained variance when multiplied by 100. In terms of Cohen’s criteria, effect sizes expressed as the percentage explained variance may be considered as small (1.0% to 5.8%, Cohen’s $d=.20$), medium (5.9% to 13.8%, Cohen’s $d=.50$), or large ($> 13.9\%$, Cohen’s $d=.80$) (Cohen, 1988). Tests were two-tailed using a $p$-value of 0.05.

RESULTS

Behavioral characteristics
Table 1 shows gender-specific means and standard deviations of the externalizing and internalizing CBCL and TPBQ dimensions.

<table>
<thead>
<tr>
<th>Boys (N=438) Mean (SD)</th>
<th>Girls (N=493) Mean (SD)</th>
<th>Boys vs girls $t$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBCL²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Externalizing</td>
<td>9.3 (7.2)</td>
<td>7.0 (5.9)</td>
<td>$t=5.8$</td>
</tr>
<tr>
<td>Internalizing</td>
<td>7.7 (5.7)</td>
<td>7.9 (6.1)</td>
<td>$t=0.2$</td>
</tr>
<tr>
<td>TPBQ³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Externalizing</td>
<td>2.7 (0.6)</td>
<td>2.5 (0.6)</td>
<td>$t=3.9$</td>
</tr>
<tr>
<td>Internalizing</td>
<td>2.7 (0.6)</td>
<td>2.6 (0.6)</td>
<td>$t=1.5$</td>
</tr>
</tbody>
</table>

Note: CBCL = Child Behavior Checklist; TPBQ = Preschool Behavior Questionnaire. ¹ by Student’s $t$-tests. ²Sumscores and ³mean scores are given.
**Externalizing and Internalizing Problems**

### Autonomic variables and gender effects

Table 2 describes autonomic variables measured in the supine and standing positions. HR was significantly higher in the standing than in the supine position, whereas RSA and BRS were lower in the standing position. Girls had higher supine and standing HR, but lower supine RSA and lower supine and standing BRS than boys. There were no gender differences regarding autonomic reactivity scores.

In both the supine and standing positions, HR was inversely related to both RSA ($r = -.63, p < .001$ and $r = -.69, p < .001$, respectively) and BRS ($r = -.52, p < .001$ and $r = -.66, p < .001$, respectively). In addition, RSA was positively correlated with BRS in both the supine ($r = .65, p < .001$) and standing positions ($r = .70, p < .001$). Furthermore, children with higher supine HR displayed lower HR reactivity ($r = -.13, p < .001$), whereas children 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. Autonomic variables measured in supine and standing positions.

<table>
<thead>
<tr>
<th></th>
<th>Supine Mean (SD)</th>
<th>Standing Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All children</strong> (N=931)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>77.7 (11.1)</td>
<td>94.3 (13.5)</td>
</tr>
<tr>
<td>RSA ln(ms²)</td>
<td>7.3 (1.3)</td>
<td>6.0 (1.3)</td>
</tr>
<tr>
<td>BRS ln(ms/mmHg)</td>
<td>2.6 (0.6)</td>
<td>2.0 (0.6)</td>
</tr>
<tr>
<td><strong>Boys</strong> (N=438)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>75.8 (10.5)</td>
<td>92.8 (13.4)</td>
</tr>
<tr>
<td>RSA ln(ms²)</td>
<td>7.5 (1.3)</td>
<td>6.0 (1.3)</td>
</tr>
<tr>
<td>BRS ln(ms/mmHg)</td>
<td>2.6 (0.6)</td>
<td>2.1 (0.6)</td>
</tr>
<tr>
<td><strong>Girls</strong> (N=493)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>79.4 (11.3)</td>
<td>95.7 (13.4)</td>
</tr>
<tr>
<td>RSA ln(ms²)</td>
<td>7.2 (1.3)</td>
<td>5.9 (1.2)</td>
</tr>
<tr>
<td>BRS ln(ms/mmHg)</td>
<td>2.5 (0.6)</td>
<td>2.0 (0.5)</td>
</tr>
</tbody>
</table>

**Note:** HR=heart rate; RSA=respiratory sinus arrhythmia (0.15-0.40 Hz); BRS=baroreflex sensitivity (0.07-0.14 Hz). Posture and gender effects by Student’s t-tests. Supine versus standing: all significant at $p < .001$. Boys versus girls: supine: all significant at $p < .001$, standing: HR $p < .001$, RSA non-significant, BRS $p < .010$. 

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Externalizing and internalizing problems

Externalizing problems

Supine. Externalizing problems were negatively associated with HR ($F_{1,926}=6.5$, $p=.011$, $\eta^2=.007$) and positively with RSA ($F_{1,926}=3.9$, $p=0.048$, $\eta^2=.004$), but unrelated to BRS ($F_{1,926}=0.1$, $p=.777$, $\eta^2=.001$).

Reactivity. Externalizing problems were not associated with HR reactivity ($F_{1,925}=0.7$, $p=.414$, $\eta^2=.001$), RSA reactivity ($F_{1,925}=1.1$, $p=.285$, $\eta^2=.001$), nor BRS reactivity ($F_{1,925}=0.5$, $p=.498$, $\eta^2=.001$).

Internalizing problems

Supine. Internalizing problems were positively related to HR ($F_{1,926}=9.1$, $p=.010$, $\eta^2=.010$) and negatively to RSA ($F_{1,926}=11.9$, $p<.001$, $\eta^2=.013$). There was no relationship with BRS ($F_{1,926}=0.4$, $p=.545$, $\eta^2=.001$).

Reactivity. Internalizing problems were not associated with HR reactivity ($F_{1,925}=0.4$, $p=.530$, $\eta^2=.001$), RSA reactivity ($F_{1,925}=1.2$, $p=.279$, $\eta^2=.001$), nor BRS reactivity ($F_{1,925}=0.1$, $p=.815$, $\eta^2=.001$).

Early presence of externalizing and internalizing problems

Tables 3 and 4 describe the results of group comparisons (‘early starters’ versus ‘current-only’ versus ‘controls’) for externalizing and internalizing problems, respectively.

Externalizing problems

Supine. Children with early starting externalizing problems had lower HR than controls. In addition to the main effect, we found a gender-behavior interaction for both RSA and BRS. Subsequent gender-stratified analyses revealed significant effects for girls only. In girls with externalizing problems, RSA of early starters was higher than of the current-only group and of controls. Likewise, in girls, BRS of early starters was higher than of the current-only group and of controls.

Reactivity. There were no significant group differences between children with early starting, current-only, and no externalizing problems regarding all autonomic difference scores, i.e., HR reactivity (early starters: $M=17.1$, 95%CI=16.0–18.2; current-only: $M=16.5$, 95%CI=15.1–17.9; controls: $M=16.2$, 95%CI=15.0–17.4; $F_{(2,722)}=0.8$, $p=.453$, $\eta^2=.002$), RSA reactivity (early starters: $M=-1.5$, 95%CI=-1.6–-1.4; current-only: $M=-1.3$, 95%CI=-1.5–-1.2; controls: $M=-1.3$, 95%CI=-1.4–-1.2; $F_{(2,722)}=2.6$, $p=.075$, $\eta^2=.007$), and BRS reactivity (early starters: $M=-0.6$, 95%CI=-0.6–-0.5; current-only: $M=-0.5$, 95%CI=-0.6–-0.4; controls: $M=-0.5$, 95%CI=-0.5–-0.4; $F_{(2,722)}=3.5$, $p=.032$, $\eta^2=.009$, non-significant after Bonferroni adjustment).
TABLE 3. Externalizing problems with and without presence at preschool age in relation to autonomic supine scores.

<table>
<thead>
<tr>
<th></th>
<th>Early starters (N=292)</th>
<th>Current-only (N=179)</th>
<th>Controls (N=261)</th>
<th>F</th>
<th>p</th>
<th>η²</th>
<th>Group differences a (p&lt;.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (bpm)</td>
<td></td>
<td></td>
<td></td>
<td>3.8</td>
<td>.022</td>
<td>.11</td>
<td>ES&lt;CL</td>
</tr>
<tr>
<td>Mean [95%CI]</td>
<td>76.3 [75.1–77.6]</td>
<td>78.0 [76.4–79.6]</td>
<td>79.0 [77.6–80.4]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRS ln (ms/mmHg)</td>
<td>2.6 [2.6–2.7]</td>
<td>2.5 [2.4–2.6]</td>
<td>2.5 [2.5–2.6]</td>
<td>3.4 b</td>
<td>.034</td>
<td>.09</td>
<td>ES&gt;CU, ES&gt;CL</td>
</tr>
</tbody>
</table>

Note: HR=heart rate; RSA=respiratory sinus arrhythmia; BRS=baroreflex sensitivity; CI=confidence interval; ES=early starters (both preschool and current problems), CU=current-only, and CL=controls. Means represent estimated marginal means adjusted for covariates. Main effects of the behavioral dimension are described in the table. Df=2,722. a Pairwise comparisons of group means followed by Bonferroni type I error adjustment. In addition to the main effect, there was a significant gender-behavior interaction (RSA: F=3.3, p=.037, η²=.009; BRS: F=3.0, p=.048, η²=.008). Subsequent gender-stratification revealed significant effects for girls only (RSA: F=9.7, p=.001, η²=.049, ES>CU, ES>CL; BRS: F=5.6, p=.004, η²=.029, ES>CU, ES>CL). RSA in girls: early starters (n=124, M=7.6, 95%CI=7.4–7.8), current-only (n=89, M=7.1, 95%CI=6.9–7.3), controls (n=166, M=7.1, 95%CI=6.9–7.3). BRS in girls: early starters (n=124, M=2.6, 95%CI=2.5–2.7), current-only (n=89, M=2.3, 95%CI=2.2–2.4), controls (n=166, M=2.4, 95%CI=2.3–2.5).

Internalizing problems

Supine. Children with early starting internalizing problems demonstrated higher HR than children with current-only problems and controls. In addition, early starters showed lower RSA compared to controls. There were no group differences regarding BRS.

Reactivity. No significant group effects were present for all three autonomic difference scores, i.e., HR reactivity (early starters: M=16.7, 95%CI=15.6–17.8; current-only: M=17.3, 95%CI=16.0–18.5; controls: M=16.2, 95%CI=15.0–17.4; F(2,710)=0.7, p=.518, η²=.002), RSA reactivity (early starters: M=1.4, 95%CI=1.5–1.3; current-only: M=1.4, 95%CI=1.3–1.5; controls: M=1.4, 95%CI=1.5–1.2; F(2,710)=1.0, p=.529, η²=.002), and BRS reactivity (early starters: M=0.6, 95%CI=0.6–0.4; current-only: M=0.5, 95%CI=0.6–0.4; controls: M=0.5, 95%CI=0.5–0.4; F(2,710)=1.7, p=.826, η²=.001).
**DISCUSSION**

Current externalizing and internalizing problems in preadolescents were related to divergent autonomic patterns: externalizing problems were associated with decreased HR and increased vagal tone, and internalizing problems with increased HR and decreased vagal tone. Moreover, these associations between both problem dimensions and autonomic function were specifically found in children with behavioral and emotional problems retrospectively reported to have been already present early in the child’s development.

Our finding of increased vagal activity associated with externalizing problems is in line with a few other studies that also used non-clinical, non-high-risk samples (Scarpa & Ollendick 2003, Slobodskaya et al. 1999), but contrasts with findings of decreased vagal activity associated with externalizing problems in selected groups (Mezzacappa et al. 1997, Pine et al. 1998). This highlights the difference between behavioral problems in the general population and high-risk samples. In addition, in girls with early starting externalizing problems, we found an increased resting BRS, as compared to a reduced BRS in impulsive boys in the study of Allen et al. (2000). Resting BRS represents largely (although not exclusively) vagal activity, as reflected by the high correlation between resting RSA and BRS in our sample. The present findings of an increased RSA and BRS in combination with a lower HR also fits well with previous research in unselected population-based samples, in which RSA was inversely correlated with HR (r=. -0.60 to . -0.80), apparently helping to slow down HR (Berntson et al. 1993). Thus, it appears that a lower HR and increased RSA or BRS in relation to externalizing problems may be primarily encountered in unselected...
community samples, which may be characterized by a relatively lower degree of behavioral problems compared to selected samples.

Several other explanations for the contrasting findings regarding vagal tone in association with externalizing problems are possible. First, gender differences may play a role. We found an increased vagal activity in association with externalizing behavior primarily in girls, whereas most studies that reported decreased vagal activity were restricted to boys (Mezzacappa et al. 1997, Pine et al. 1998). This is of particular interest, given the known lower prevalence of externalizing behavior in girls in comparison to boys and the generally lower vagal tone in girls. Second, previous studies mostly did not control externalizing behavior for internalizing problems. Failing to do so may affect the relationship between vagal function and externalizing problems (Pine et al. 1996), since comorbidity between externalizing and internalizing problems is common (Bauer et al. 2002), and internalizing problems have been associated with reduced vagal activity (Monk et al. 2001). Finally, vagal activity may be differentially related to specific types of externalizing behavior (Scarpa & Raine 1997). In one study, lower HR and increased RSA were specifically related to proactive but not reactive aggression (Van Voorhees & Scarpa 2002). Proactive aggression tends to be unemotional and goal-directed, whereas reactive aggression is emotional, impulsive, and defensive (Scarpa & Raine 1997). In line with this, higher vagal tone has been found to be associated with increased self-regulation and decreased negative emotional arousal when confronted with moderate-to-high level stressors (Fabes & Eisenberg 1997), whereas lower vagal tone plays a role in emotional lability and negative affect (Porges et al. 1994). Thus, our results of reduced HR and increased vagal tone in relation to externalizing problems could be explained by the presence of a kind of externalizing behavior characterized by a high degree of emotion regulation and low levels of negative emotionality, which has been associated with increased vagal activity (Scarpa & Raine 1997). Clearly, more research is needed to more fully understand the relationship between vagal function and externalizing psychopathology, preferably testing specific hypotheses regarding type and severity of externalizing symptoms.

In accordance with the concept of autonomic overarousal, we found internalizing problems to be associated with increased resting HR (Kagan et al. 1988, Kagan et al. 1994). Also, in keeping with the literature (Monk et al. 2001), internalizing problems were related to lower vagal tone, as indexed by RSA. This is consistent with the view that reduced vagal function reflects deficient emotion regulation (Porges et al. 1994). Decreased vagal activity has been tentatively linked to dysfunction of limbic brain structures, in particular the amygdala (Kagan et al. 1988). Future studies could prospectively investigate whether children with internalizing problems combined with an autonomic profile characterized by a higher HR and lower RSA would be at increased risk for future anxiety disorders or depression.

Internalizing problems, however, were unrelated to BRS in this sample. This is somewhat surprising, when regarding the present high correlation between
RSA and BRS, and the inverse relationship between RSA and internalizing problems. Compared to RSA, which is an index of vagal activity, BRS reflects both sympathetic and vagal activity. Thus, differences in sympathetic function in relation to internalizing problems may have played a role in explaining the present result. More research is needed to elucidate the relationship between BRS and internalizing problems, given the lack of studies in children and the inconclusive findings in adults (Broadley et al. 2005, Virtanen et al. 2003, Volkers et al. 2004). Future studies might consider comparing different types of internalizing problems in relation to baroreflex function.

Finally, we tested the hypothesis that psychological functioning is related to basic autonomic reactions to orthostatic challenge, as had been suggested previously (Mezzacappa et al. 1997, Yeragani et al. 1991). However, we found no relationship between children’s behavior profiles and autonomic reactivity scores. In contrast to most studies, we adjusted reactivity scores for baseline autonomic levels, in order to rule out the influence of initial baseline (supine) levels on the magnitude of difference scores (Beauchaine 2001, Benjamin 1963). The failure to control for initial values complicates a proper interpretation of the results of many previous studies (Beauchaine 2001). The present negative findings with regard to orthostatic challenge indicate that externalizing and internalizing problems are not linked with reflexive physiological processes at brainstem level, given that orthostatic stress predominantly engages brainstem systems (Berntson & Cacioppo 2004). In contrast, psychological stressors may induce activation of higher central brain structures, such as the limbic system or frontal cortex involved in behavior and emotion regulation (Kagan et al. 1988). Based on the present findings, we cannot recommend orthostatic challenge as an autonomic stress test in future psychophysiological research.

**Limitations**

Participants’ age was restricted to preadolescence, which may limit generalization of findings to other age groups. Another weakness may have been the use of single informants (parent reports) rather than multiple informants (parent- and child reports) to assess externalizing and internalizing problems. However, given the exploratory nature of this study, and given that parents and children have been shown to rarely agree on the presence of diagnostic conditions, regardless of diagnostic type (Jensen et al. 1999), we thought it best to use only one source of information to assess psychopathology, and judged parents to be the most reliable source. However, in relying on parent reports, we may have underestimated children’s internalizing problems, since parents may not be fully aware of their child’s anxiety or depressive symptoms, especially when children approach adolescence. Future studies may certainly use multiple informants to increase diagnostic reliability.

Another limitation of this study was that children’s preschool problems were determined in retrospect by a non-validated instrument. Bias by current state may be involved, i.e., parents of children with more severe current problems may have been more likely to report early problems, whether they were or were not...
present. Thus, early problems may have been overrated. Hence, the results regarding the role of early problems in relation to autonomic function should be regarded as preliminary and await confirmation in prospective studies. Furthermore, the current results do not allow inferences about causality. In theory, behavioral and emotional problems may either result from or influence autonomic function, or underlying factors may independently determine behavior as well as autonomic function.

Finally, data were not collected in standardized laboratory conditions, but at schools. This may have contributed to the large inter-individual differences in autonomic measures that may partly explain the small effect sizes. However, these small effect sizes should also be seen in the light of the use of a large population cohort, with rather nonspecific and relatively mild levels of behavioral and emotional problems. Larger effect sizes may be expected in clinical groups with more severe levels of psychopathology.

Clinical Implications

In conclusion, the present large preadolescent population study confirms earlier smaller-scale investigations that had pointed to an association between autonomic underarousal and externalizing problems as well as between autonomic overarousal and internalizing problems. Moreover, it provides new, if preliminary evidence that problems starting early in children’s development may specifically account for these associations. The latter possibility should certainly be the focus of future, preferably prospective, research.

The present findings may serve clinicians to better understand children’s externalizing and internalizing problems: autonomic underarousal may facilitate risk-taking and disruptive behavior, whereas autonomic overarousal may play a role in behavioral withdrawal.
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CHAPTER 5 Externalizing and Internalizing Problems


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