Autonomic nervous system function and behavioral characteristics in (pre)adolescents from a general population cohort
Dietrich, Andrea

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2007

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):
Dietrich, A. (2007). Autonomic nervous system function and behavioral characteristics in (pre)adolescents from a general population cohort. s.n.

Copyright
Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

Take-down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): http://www.rug.nl/research/portal. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Download date: 19-06-2019
CHAPTER 7

GENERAL DISCUSSION
The studies of this thesis focused on autonomic function in a large population cohort of (pre)adolescents and the relationship between autonomic function and behavioral characteristics. The first study was undertaken to gain more insight into demographic and general health determinants of baroreflex sensitivity (BRS) in a large population cohort of (pre)adolescents. Here, we found that BRS is negatively associated with gender, age, and the presence of obesity. In the two subsequent studies, the relationship between autonomic function and both temperament and psychopathology was explored. So far, this had not been systematically investigated in large-scale samples, with studies with regard to BRS completely lacking. Results suggested a physiological basis promoting the tendency towards engagement in activities with high intensities. Moreover, it appeared 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 of heart rate (HR) and blood pressure (BP), which implicates healthy physiological functioning. In contrast to findings regarding temperament, externalizing and internalizing problems were found to be associated with divergent autonomic patterns, suggesting autonomic underarousal and overarousal, respectively. Finally, to better evaluate the findings of the first three studies, the reproducibility of a number of autonomic function indices was investigated in a smaller group of children.

In the following sections of this final chapter, we will first discuss the overall strengths and weaknesses regarding the present set of studies. This will include factors associated with the use of our study sample, a large general population cohort, in addition to a critical review of the methods we chose to assess both autonomic function and the behavioral characteristics. The results of the reproducibility study put the sometimes weak associations which we encountered in context and indicate that these may at least in part be understood by intrinsic variations of the measures. This is most salient with regard to the standing-induced reactivity measures. We will provide a general discussion of our main findings, before presenting suggestions for future research and clinical implications followed by the overall conclusions of our studies.

**STRENGTHS AND WEAKNESSES**

**Study sample**

Studying a large population sample has several major advantages. It allows for the detection of small effects due to the high power associated with large samples. The use of small samples has often been put forward as an explanation for the inconsistent findings in the literature regarding the relationship between autonomic function and behavioral characteristics. In addition, using large samples facilitates the investigation of gender differences. So far, many studies on the link between
autonomic measures and behavior had focused exclusively on males. Furthermore, the large sample enabled us to investigate specific subgroups, i.e., children with or without behavioral and emotional problems early in life.

A disadvantage of our study may have been the narrow age range of the participants, which limits conclusions concerning the development of autonomic function. Also, it is unclear whether our findings generalize to other age groups. However, studies in (pre)adolescents are sparse, thus, our studies provide new insights into autonomic function of individuals in this age range.

Another important aspect when using a large cohort from the general population, is, by definition, the inclusion of a large number of subjects within the normal range of functioning, both with respect to autonomic and behavioral measures. This may have attenuated autonomic-behavioral relationships, especially when regarding the wide inter-individual variability in autonomic measures. However, studying an epidemiological sample allows for estimating the relevance of associations in the general population. With the exception of studies on the relationship between HR and externalizing psychopathology, few large-scale population studies on autonomic function exist in children and adolescents. Many previous studies have used specifically selected high-risk groups, such as younger brothers of adjudicated delinquents (Pine et al. 1998). It is unclear whether these findings also generalize to milder problems as may be found in the general population.

Finally, the cross-sectional nature of the present investigations limit the ability to draw causal inferences. Autonomic function may determine behavior or may be influenced and shaped by behavior, or both factors may have a common underlying cause.

Autonomic measures
A solid methodology is of vital importance for the outcome of research on autonomic function. Several points may have negatively influenced the reliability of our autonomic measurements. Compared to scientific standards, signal recording periods were relatively short, at least 5 minutes of continuous HR and BP measurements have been recommended (Task Force 1996). Particularly, the measurements in standing position were probably too short (2 minutes only), which also explains the large amount of data loss in this condition. Also, pre-measurement resting periods lasted a few minutes at best. On the other hand, experiences with this kind of measurements were good in our own laboratory, our pilot study indicated good usability of the cardiovascular data, and a comparable methodology has also been applied in previous studies (Lefrandt et al. 1999). In addition, we found high internal reliability of BRS in our study described in chapter 3, in which periods of 200 seconds of signal recordings were compared with the respective first and second period of 100 seconds.
Measurement error in autonomic scores may have also been introduced by performing the assessments at schools, where conditions are less standardized compared to a laboratory situation. For example, there was no control of room temperature, mealtime, and pre-assessment physical activity. Some children were assessed immediately after a break or the gymnastic classes. In such cases we usually extended the resting period for a few minutes before starting the recordings, but pre-measurement resting periods may nevertheless have been too short. Furthermore, although most assessments took place in quiet and private conditions, emotional and sensorial influences could not be ruled out completely. For example, some children had to lie on the floor in large halls with people walking around, or they had to lie on high, narrow tables in cramped rooms, with a group of singing pupils next door. Another problem during the winter season were cold hands, which explains some of the difficulties in BP measurements (although we always checked for cold hands and tried to warm them up by rubbing the hands and/or cover them with a piece of cloth). Thus, measurement conditions may not have been ideal in some cases. Still, measurements at school may have been less stressful than in a laboratory, since children were in an acquainted environment.

Another source of measurement variation may have been the use of spontaneous instead of paced breathing (Pitzalis et al. 1996), although controlled-breathing procedures also have been shown to have disadvantages in that these may affect autonomic cardiovascular control (Pinna et al. 2006). When breathing spontaneously, children do differ in their breathing patterns, with primary influences on the respiratory-based high frequency oscillations of HR (Saul et al. 1991). Still, the method of spontaneous breathing has found wide application and provides sufficiently reliable autonomic measurements, provided that individuals breathe normally and avoid slow or irregular breathing (Pinna et al. 2006).

Furthermore, hands were not kept at heart level, which, against our expectations could not entirely be controlled for by our software program assessing the distance between the heart and finger plethysmograph. Other sources of variability in autonomic scores were the wear and tear of the apparatus and the large number of assistants who performed and analyzed the autonomic recordings.

Despite all these potentially disturbing influences, we found, in general, similar absolute autonomic values as other investigators, who also reported large inter-individual variability of measures of autonomic function (Tanaka et al. 1994). Moreover, we expected that the sample size of our population study would be large enough to counterbalance the possible methodological flaws and to compensate for random fluctuations in individual values.

To gain better insight into the reliability of our own autonomic measurements and to evaluate effect sizes in our previous three studies, we conducted the study on short-term reproducibility in a small sample of children. Whereas HR and heart rate variability (HRV) were highly reproducible, BP and BRS were at best moderately, and standing-induced reactivity scores only poorly reproducible.
These findings should be seen in the light of the present methodology: the short measurement periods may have decreased reproducibility. Also, the result of poor reproducibility regarding standing-induced autonomic reactivity may not generalize to other types of stressors, such as psychological stress. In addition, the results regarding BP only apply to Portapres measurements, a noninvasive continuous BP monitoring system, known to show more variability in BP values compared to other methods (Tanaka et al. 1994) and therefore to be possibly less reproducible. Similarly, absolute values of BRS, which may serve other researchers or clinicians as reference, largely depend on the methods used. However, alternative (invasive) measurements of continuous BP or BRS may not always be available or applicable, certainly not in large-scale pediatric populations. Thus, the results of our studies are primarily relevant to investigations that use a comparable methodology.

One should also bear in mind that the interpretation of the level of reproducibility depends on a number of, rather arbitrary, factors that may vary from study to study. Different cut-off points and labels have been used to categorize reproducibility as, for example, poor, moderate, or satisfying. In addition, conclusions on reproducibility depend on the kind and number of statistical methods involved. We aimed to thoroughly investigate reproducibility of autonomic variables, using several well-known, accepted methods. As becomes clear, the field could be greatly advanced by the use of universally accepted ways to analyze and interpret reproducibility of autonomic measures.

Moreover, judging if a level of reproducibility is satisfactory, may largely depend on the purpose for which the autonomic measurements are used. For clinical applications, obviously a higher level of reproducibility of autonomic measures is needed than for research purposes. Here, again, interpretations of what is poor or good reproducibility is a matter of judgment. In cohort studies, lower levels of reproducibility may be counterbalanced by the use of a larger sample size, to outweigh the magnitude of error versus the true variability of scores in order to increase the power to detect effects.

A final question is to what degree the results of the small-scale reproducibility study can be generalized to the large population cohort. In the reproducibility study, we applied principally the same methodology as in the population cohort, except for a few minor differences. First, in the small-scale study, children were asked not to participate in demanding physical exercise the day before the cardiovascular assessment, whereas there was no control of physical activity in the cohort study. Second, measurement periods in the reliability study tended to be a bit longer (4.5 and 3.3 minutes versus 4 and 2 minutes in the supine and standing positions, respectively), and third, the high frequency oscillations ranged from .15-.50 Hz instead of .15-.40 Hz. The wider high frequency range of the reproducibility study may have introduced some noise to the data, which were, however, likely to be compensated by the longer measurements. Therefore, overall differences in methodology were only minor. Indeed, absolute values of autonomic variables
were nearly identical in both studies [except for blood pressure variability (BPV), for which we have no explanation]. However, autonomic variables showed much more variation in the population cohort, with wider ranges and much larger standard deviations. This may be partly understood by the increased risk of errors related to the cardiovascular data analyses and administration of a large number of data (e.g., unreliable measurements may have been falsely included). A dataset of 68 measurements may be more easily dealt with than a dataset of more than 3,500 measurements. Therefore, it is conceivable that the reliability of autonomic measures of the population sample is lower than indicated in the small-scale reproducibility study.

**Behavioral measures**

A strength of our studies on the relationship between autonomic function and behavioral variables was the inclusion of dimensions of both temperamental activation and inhibition, and both externalizing and internalizing psychopathology, respectively. This allowed us to study interactions between both dimensions and to adjust for the influence of the other. The latter may have been particularly important, given that both dimension may be independently related to autonomic function and symptoms of both behavioral dimensions often co-occur. Many previous studies had focused on only one type of behavior, which may have influenced results (Pine et al. 1996).

A weakness regarding the study of temperament may have been the use of a questionnaire that was not specifically designed to measure temperamental activation and inhibition. However, we chose the two basic variables of our instrument that were most closely related to these temperamental dimensions, i.e., high-intensity pleasure and shyness. We suggest that future research use the Behavioral Inhibition System and Behavioral Activation System (BIS-BAS) scales (Carver & White 1994).

Preschool externalizing and internalizing problems were assessed by retrospective parent reports on a non-validated questionnaire. Retrospective measures of behavioral functioning may be affected by possible reporter bias. Hence, conclusions based on this measure should be regarded as preliminary. Nevertheless, our finding that associations between autonomic function and externalizing and internalizing problems were specifically observed in children with problems retrospectively reported also to have been present at preschool age, is important. This has rarely been studied, our findings thus contribute to the scientific discussion on the relevance of early behavioral and emotional problems in relation to autonomic function.

Another point of criticism may be the reliance on parent reports as the only source of information, rather than on multiple informants, such as child or teacher reports. It has been suggested that at least older children may be better indicators of emotional problems than their parents. However, in our opinion, there is presently
no gold standard as to which (single or multiple) informant is the most valid indicator of psychopathology. Given the exploratory nature of our study, we focused on parent reports whom we judged to be the most reliable source of information, also given the still young age of the participants. We also used parent reports to be in line with the measures used to assess early problems.

Finally, our investigations with regard to temperament and psychopathology may be complicated by the fact that both the constructs of temperament and psychopathology are closely related (Nigg 2006) and that we did not adjust for the influence of the other. However, we preferred to first study each variable in its own right, given the inconsistencies in the literature regarding the relationship between autonomic function and respectively temperament and psychopathology.

DISCUSSION OF MAIN FINDINGS

Autonomic function in association with temperament and psychopathology

In the following, we will focus on the integration of our findings on autonomic function in relation to both temperament and psychopathology. Within each, we were interested to find specific autonomic profiles to be associated with the dimensional poles, i.e., temperamental activation versus temperamental inhibition, and externalizing versus internalizing psychopathology. We also wanted to explore whether autonomic patterns would distinguish between temperament and psychopathology. For example, temperament might be associated with increased vagal activity and psychopathology with decreased vagal activity, since temperament has been associated with ‘healthy’ and psychopathology with ‘abnormal’ psychological functioning.

The hypothesis that temperamental activation and temperamental inhibition would be characterized by clearly different autonomic profiles could not be confirmed. The most convincing evidence for an association between temperament and autonomic function was found for temperamental activation, which was defined as high-intensity pleasure (i.e., pleasure derived from activities involving high intensity or novelty). Our study provides new evidence for autonomic underarousal (as indicated by a lower HR) in (pre)adolescents with a pleasure-seeking temperament; only a few earlier studies have reported on this before (Scarpa et al. 1997, Raine et al. 1997, Zuckerman 1990). Theoretically, this association may also be explained by the link between temperamental activation and externalizing problems (Leve et al. 2005, Raine 1996, Raine et al. 1998), in that aggressive or rule-breaking individuals may be characterized by a pleasure-seeking temperament. Our study forms a good starting point for future research that could concurrently analyze both temperament and psychopathology in relation to autonomic function.
In chapter 4, we suggested that the observed higher resting RSA and BRS (indices of vagal activity) in relation to temperamental activation may reflect a healthy behavioral style, referring to the ideas of Porges and others (Beauchaine 2001, Porges et al. 1996, Thayer & Brosschot 2005). The study of temperament could be particularly well-suited to investigate this proposition, since temperament is, at least in theory, assumed to largely reflect normal functioning as compared to psychopathology. However, our study on psychopathology also demonstrated a higher RSA and BRS associated with externalizing problems. Thus, increased vagal activity appears not to be exclusively associated with temperament, but also with psychopathology. This is quite surprising, considering the general evidence for decreased vagal activity associated with externalizing psychopathology in the literature (Beauchaine et al. 2001, Mezzacappa et al. 1997, Pine et al. 1998), although a few studies have also shown a higher RSA related to externalizing psychopathology, in population-based, non-high-risk samples (Scarpa & Ollendick 2003, Slobodskaya et al. 1999).

In chapter 5, we extensively discussed the rather new finding of increased RSA and BRS in relation to externalizing problems, for which no immediately evident explanations are available. To follow the line of reasoning of Porges, externalizing problems as measured in our study in (pre)adolescents would be associated with adaptability to meet environmental demands, or, to put it short, would be ‘adaptive or represent well-functioning’. This description appears counterintuitive at first sight, given that behavior problems are supposed to represent psychological (and therefore possibly also physiological) abnormality. However, Porges’ ideas fit well with the notion that individuals with externalizing behavior primarily do not experience problems themselves (to a certain degree, of course), but that it is the environment that suffers most from such behaviors. Thus, in a way, being (mildly) aggressive or behaving in a rule-breaking manner may be an adaptive behavioral style. This may specifically be true for girls, as the present finding primarily applied to girls. Taken together, increased vagal activity is not specifically associated with temperamental activation, but also with externalizing psychopathology.

In contrast to our expectations, temperamental inhibition was not associated with HR and RSA, but, remarkably, with increased BRS, if only in girls. We pointed out that shyness in girls appears to be characterized by a well-functioning autonomic regulation system. This finding is rather intriguing and has, to our knowledge, not been reported before. We suggested that shyness might be a physiologically adaptive trait, which would fit to typical gender roles, in that shyness may be considered a normal, adaptive characteristic in girls but not in boys. Inhibition typically has been associated with a higher HR and lower vagal activity, which we indeed found in (pre)adolescents with internalizing problems. This autonomic pattern might indicate autonomic overarousal and increased stress vulnerability (Porges 1992, Porges 1995). Thus, with respect to inhibition, there was a clear difference in autonomic function between measures of temperament and of
psychopathology, which does support the idea that both are characterized by specific autonomic profiles. This might be explained by differences in severity of inhibited behavior, but might also result from differences in the definition of both temperament and psychopathology in our study. Shyness specifically referred to social anxiety, whereas the broad-band dimension of internalizing problems included anxiety, depression, and physical symptoms.

Overall, inter-relationships between the autonomic measures and behavioral indices were coherent. For example, a lower HR can be understood as a consequence of increased vagal influences on the heart (as measured by resting RSA or BRS), whereas a higher HR may be explained by reduced vagal influences (Beauchaine 2001). These patterns were found across all behavior dimensions, with the exception of temperamental inhibition that was only related to increased BRS. We did not always find associations of the behavioral parameters with both RSA and BRS, which may result from the fact that, although these measures are highly correlated, they do not represent identical autonomic processes.

In conclusion, we found evidence for specific autonomic profiles in association with both dimensional poles of psychopathology (i.e., externalizing versus internalizing), but not of temperament (i.e., activation versus inhibition). Moreover, autonomic patterns did not clearly distinguish between temperament and psychopathology. Autonomic profiles of temperamental activation mirrored those of externalizing psychopathology, whereas autonomic patterns of temperamental inhibition differed from those of internalizing problems. Thus, overall, the relationships between autonomic function and behavioral variables appear complex, but still coherent.

**Understanding the strength of relationships – taking both reproducibility and the use of a population cohort into account**

Finally, it is important to integrate our findings on demographic and behavioral variables with those of the reproducibility study in chapter 6. The reported small effect sizes or even lack of significant associations between autonomic function and demographic or behavioral variables might in part be explained by low reproducibility of autonomic measures. Indeed, autonomic reactivity scores showed insufficient test-retest reliability; hence, the non-significant results regarding autonomic reactivity and temperament as well as psychopathology are not surprising. Furthermore, the poor-to-moderate reproducibility of supine BRS explains the lower effect sizes of BRS compared to RSA, and perhaps also a few non-significant results.

However, despite the good reproducibility of HR and RSA, effect sizes of HR and RSA were small in our behavioral studies. In other words, these cannot be explained by a low level of reproducibility. Other factors may play a role in understanding the small effects, such as the large inter-individual variability in autonomic scores, in combination with the generally low level of extreme behavioral
measures. Preadolescence can be considered a phase in children’s development in which the influence of temperament on current behavior is relatively small when compared to a younger age, and major psychiatric symptomatology is yet to emerge. In this respect, the role we found for early present problems as described in chapter 5 is most interesting. Irrespective of the participants’ age, levels of psychopathology in a population cohort are low. This also raises the question as to the relevance of our findings in the general population. Associations between autonomic function and behavior do not appear to be of major importance from an epidemiological perspective. Possibly, investigating the relationship between autonomic function and behavioral characteristics (or psychopathology) in clinical or high-risk samples would result in a more fruitful approach, with larger effect sizes to be found.

Also, the behavioral measures themselves include a certain amount of measurement unreliability. It is furthermore important to notice that behavioral characteristics are likely to be associated with a variety of environmental and biological factors, of which autonomic function is just one aspect. In general, associations between autonomic function and behavioral characteristics have been found to be small in the literature (between 1-7% in psychophysiological research).

Baroreflex sensitivity – worth the effort for behavioral studies in children and adolescents?

BRS is a sensitive measure of the balance of sympathetic and parasympathetic activity and provides insights into the function of an important regulatory mechanism of the autonomic nervous system, that of short-term BP control. HRV is determined largely by two main functions, respiration and baroreflex control. Thus, baroreflex function lies on the base of HRV. Also, BRS describes the transfer function between HRV and BPV. Therefore, BRS is a more sophisticated autonomic measure than HRV. Furthermore, a reduced BRS has been found to be a valuable predictor of future cardiovascular health (La Rovere et al. 1998) and has also been related to psychological functioning (Broadley et al. 2005, Watkins et al. 1999). These considerations stress the relevance of BRS.

However, when considering our overall results on BRS in relation to temperament and psychopathology, the question rises how worthwhile measurements of BRS are in children and adolescents. Based on associations with BRS, behavioral parameters did not turn out to be related to autonomic dysfunction. Rather, a higher BRS was associated with temperamental activation and inhibition, and with externalizing problems, mostly in girls. The meaning of a higher BRS is not exactly clear. Should this be interpreted as an indication of better autonomic function, as we did in the chapters 4 and 5, or should we be mainly interested in (reduced) BRS as an indicator of autonomic dysfunction?

Another problem lies in the uncertainty of the autonomic background of BRS. A higher resting BRS has been generally interpreted in terms of increased
parasympathetic activity, although, strictly speaking, BRS also reflects sympathetic activity. Thus, the interpretation of BRS is complicated by the fact that it is a measure of sympathovagal balance. Available theories in psychophysiology are primarily concerned with either sympathetic or parasympathetic autonomic function (e.g., arousal theory, vagal brake theory). Hence, it is difficult to place BRS in existing theoretical frameworks. In this respect, investigating specific measures of sympathetic or parasympathetic activity (e.g., electrodermal responses, pre-ejection period, RSA) might be a better choice than assessing BRS, especially when resources are limited, given that BRS assessments are very time consuming and expensive. A final issue of concern is the at best moderate reproducibility of BRS.

In conclusion, when deciding on whether or not to investigate BRS in relation to psychological functioning, possible advantages and disadvantages of BRS measurements should be carefully considered.

**Autonomic reactivity to orthostatic stress – relevant in association with psychological functioning?**

We did not find an association between autonomic reactivity induced by orthostatic stress and both temperament and psychopathology. Several considerations, discussed in chapter 5, led to the inclusion of orthostatic challenge as a measure of stress in this thesis, instead of psychological stressors (such as mental tasks or public speaking), which are commonly applied in psychophysiological research. During the setup of the study, the primary idea to include orthostatic stress was to gain more insight into autonomic regulation and adaptation (Pagani & Malliani 2000). Challenging situations might be better suited to find meaningful relationships than static ones. For example, a low BRS reactivity (i.e., a limited decrease in BRS upon standing, where normally a large decrease would be expected) could point to defects in autonomic function. In the medical field and in basic physiological science, the orthostatic stress test is a well-established measure of autonomic function.

However, from a psychologists’ point of view, the main interest is in autonomic reactions to psychologically stressful situations. Theoretically, autonomic hyper-reactivity to psychologically stressful situations (i.e., increased stress responses) could be an important etiological factor to explain psychiatric, and perhaps also cardiovascular diseases (e.g., cardiovascular reactivity hypothesis; Matthews et al. 2006, Potempa 1994). However, emotionally neutral, physical challenges such as standing obviously do not trigger a psychologically stressful response. In addition, as previously discussed, measures of autonomic reactivity were not reproducible in our study.

Thus, given theoretical concerns, poor test-retest reliability, and the lack of significant associations with behavioral parameters regarding standing-induced autonomic reactivity, in our opinion, this measure is of limited use for studies on psychological functioning.
FUTURE RESEARCH

Future research could focus on clinical or specific high-risk populations, which are likely to be characterized by more severe psychopathology compared to population cohorts and in which larger associations between autonomic function and behavioral characteristics might be found. High-risk populations might include children who have experienced extensive or long-standing externalizing or internalizing problems, which may have begun already early in life. Also, different age ranges may be interesting to investigate (e.g., during ‘vulnerable’ periods, such as toddlerhood or adolescence), given that these may be associated with more variance in behavioral characteristics and more extreme behaviors.

Furthermore, measures of psychological stress (e.g., public speaking) as well as indices of sympathetic autonomic activity (e.g., electrodermal responses) could be included to investigate individual differences in stress reactivity, which might predispose to the development of psychopathology. It would also be interesting to gain a better understanding of concurrent sympathetic and parasympathetic activity. Finally, future studies on autonomic function (especially regarding BP indices and BRS) might be aimed at increasing reproducibility and therefore effect sizes by measuring longer periods of time, averaging repeated measurement sessions, or exerting tighter control of external variables (e.g., exercise) that may negatively influence reproducibility (Kamarck & Lovallo 2003, Swain & Suls 1996).

As a follow up to our first study on demographic and general health determinants of BRS, we suggest that longitudinal studies should investigate the development of baroreflex regulation from childhood and adolescence to adulthood and provide normal values of BRS at different ages. Also, reduced BRS associated with obesity warrants further investigation as a possible predictor of cardiovascular health.

Although many of our findings on the association between autonomic function and behavioral characteristics were in line with current theories (Porges et al. 1996, Raine 2002, Zuckerman 1990), some of our results added to the inconsistencies in the literature. Despite the use of a large sample, non-significant results of HR and RSA in relation to temperamental inhibition (i.e., shyness) were found, which cannot easily be explained. In addition, replication of our result of an increased BRS associated with temperamental inhibition (in girls) is needed. The use of well-established measures of temperamental activation and inhibition, such as the BIS-BAS scales (Carver & White 1994) may lead to more consistent results.

Our study on psychopathology in chapter 5 pointed to the interesting relationship between increased vagal activity and externalizing problems. We suggested that vagal activity may be related to the severity or type of externalizing problems. Future research is needed to more fully understand this relationship, for example, in clinical versus healthy cohorts, or by investigating proactive versus reactive aggression.
CHAPTER 7 General Discussion

Future research might investigate prospective relationships between autonomic function and behavioral characteristics. Our finding of an autonomic profile consisting of a higher HR and lower vagal activity in preadolescents with internalizing problems might indicate autonomic dysfunction and increased autonomic arousability or stress sensitivity (Porges 1992, Porges 1995). This profile, whether or not in relation to current internalizing problems may be associated with increased risk for future anxiety disorders or depression (Kagan & Snidman 1999). Longitudinal studies could investigate this. Likewise, it would be interesting to study autonomic function as a predictor of future externalizing disorders, such as attention deficit hyperactivity or conduct disorder.

Prospective studies are also needed to confirm our preliminary evidence that current associations between autonomic function and externalizing and internalizing problems are primarily found in children with problems that have been reported to be also present early in life. Children with early behavioral and emotional problems might be particularly vulnerable to deviant autonomic function and the development of psychopathology.

CLINICAL IMPLICATIONS

Knowledge of normal BRS in children and adolescents may be of use as a reference to the pediatrician interested in abnormal baroreflex control in this age group. Moreover, from the perspective of reliability, our results suggest HR and HRV to be the most reliable measures for application in clinical practice.

The results of our studies regarding temperament and psychopathology might offer clinicians and parents a neurobiological framework for understanding temperamental differences between children, as well as children’s externalizing and internalizing problems. An autonomic profile of reduced HR and increased RSA (as an index of vagal activity) may indicate a lower level of autonomic arousability or stress sensitivity, which may promote the tendency towards engagement in activities with high intensities and facilitate risk-taking and disruptive behaviors. An autonomic profile of increased HR and decreased RSA may reflect a higher level of autonomic arousability or stress sensitivity, which may play a role in behavioral withdrawal.

CONCLUDING REMARKS

The present thesis has shown that research involving autonomic measures in relation to psychological functioning identifies intriguing associations, which, however, cannot be unambiguously interpreted. Our main purpose was to shed more light on the inconsistencies in the literature, which were mostly based on small, non-representative samples. Some of these inconsistencies have indeed been
cleared. It now appears plausible that internalizing problems are associated with an increased HR and decreased vagal activity. However, new questions have emerged and other remained unanswered. For example, whether temperamental inhibition is related to increased HR and decreased vagal activity as suggested in the literature is still not clear. Also, the importance of increased vagal activity in association with the activation-externalizing dimension and temperamental inhibition remains to be determined. Vagal activity appears to be a non-specific marker of behavioral characteristics, as already previously acknowledged (Beauchaine 2001). Despite these complexities, overall, it may be concluded that autonomic function is associated with temperament and psychopathology. Ultimately, the identification of biological correlates of temperament and psychopathology may further our understanding of the etiology of mental disorders (Whittle et al. 2006) and facilitate early risk detection and prevention of psychopathology in youth. In addition, the present findings may be an interesting starting point for genetic studies.
REFERENCES


