Biological Psychology 81 (2009) 67–73

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Temperamental activation and inhibition associated with autonomic function in preadolescents. The TRAILS study

Andrea Dietrich [a,b,*], Harriëtte Riese [a,c], Arie M. van Roon [d], Ruud B. Minderaa [b], Albertine J. Oldehinkel [a,e], Jan Neeleman [a], Judith G.M. Rosmalen [a]

[a] Interdisciplinary Center for Psychiatric Epidemiology, University Medical Center Groningen, University of Groningen, P.O. Box 30001, 9700 RB Groningen, The Netherlands
[b] Department of Child and Adolescent Psychiatry, University Medical Center Groningen, University of Groningen, P.O. Box 660, 9700 AR Groningen, The Netherlands
[c] Unit of Genetic Epidemiology and Bioinformatics, University Medical Center Groningen, University of Groningen, P.O. Box 30001, 9700 RB Groningen, The Netherlands
[d] Department of Internal Medicine, University Medical Center Groningen, University of Groningen, P.O. Box 30001, 9700 RB Groningen, The Netherlands
[e] Department of Child and Adolescent Psychiatry, Erasmus Medical Center Rotterdam – Sophia Children's Hospital, Dr. Molewaterplein 60, 3015 GJ Rotterdam, The Netherlands

ARTICLE INFO

Article history:
Received 19 February 2008
Accepted 6 February 2009
Available online 13 February 2009

Keywords:
Autonomic nervous system
Baroreflex sensitivity
Children
Inhibition
Respiratory sinus arrhythmia
Sensation-seeking
Shyness
Temperament

ABSTRACT

We investigated the temperamental traits high-intensity pleasure (temperamental activation) and shyness (temperamental inhibition) in relation to autonomic function as measured by heart rate (HR), respiratory sinus arrhythmia (RSA), and baroreflex sensitivity (BRS) in 938 10–13-year-old preadolescents from a population cohort. Temperament was evaluated by parent reports on the Revised Early Adolescent Temperament Questionnaire. Autonomic measurements were obtained in supine and standing position. High-intensity pleasure was negatively associated with supine HR and positively with supine RSA and BRS in both genders. Shyness was positively related to supine BRS in girls only. Orthostatic-based autonomic reactivity (difference) scores adjusted for supine values were unrelated to temperamental measures. It appeared that higher scores on temperamental activation and inhibition are associated with higher cardiac vagal activity (RSA) and/or flexible regulation of autonomic balance (BRS), implicating healthy physiological functioning. Moreover, results suggest a physiological basis promoting the tendency towards engagement in high-intensity activities.

1. Introduction

Temperament refers to individual differences in overt behavior, emotion, and motivational styles. Two core dimensions of temperament may be distinguished: activation, referring to an approaching and disinhibited behavioral style, and inhibition, comprising avoidant behaviors and withdrawal responses from unfamiliar situations guided by feelings of anxiety (Elliot and Thrash, 2002; Kagan et al., 1994).

Differences in temperament are thought to have an underlying neurobiological basis (Strelau, 1994). Considerable support has indeed been found for an association between temperament and autonomic nervous system functioning, although not universally so. Research in this field has traditionally focused on heart rate (HR), which is influenced by both sympathetic and parasympathetic (vagal) activity. Low HR is thought to reflect a low level of sympathetic arousal. The stimulation-seeking theory states that this is physiologically unpleasant and may lead to engagement in exciting, sensation-seeking (approaching) behaviors that increase the low arousal level to an optimal or normal level (Eysenck, 1997). In contrast, pioneering work by Kagan and colleagues has suggested that high HR may be characteristic of individuals who are prone to extreme fearfulness and withdrawal from unfamiliar situations (Kagan et al., 1987, 1988, 1994). Indeed, the notion of an autonomic pattern reflecting autonomic overarousal in inhibition has longstanding support in the literature (Friedman, 2007).

In the past years, indices of cardiac vagal activity [such as heart rate variability (HRV) and respiratory sinus arrhythmia (RSA)] have become increasingly important as psychophysiological markers of emotion regulation and a wide range of other psychological variables (Beauchaine, 2001; Beauchaine et al., 2007; Berntson et al., 1997; Movius and Allen, 2005). The influential polyvagal theory provides a framework for the role of the parasympathetic system in children's emotion regulation and behavioral adjustment (Beauchaine et al., 2007; Porges, 1995, 2007; Porges et al., 1996). Increased cardiac vagal activity is thought to be associated with increased openness to new experiences, active engagement with and temperamental responsivity to the environment, and to

* Corresponding author at: Department of Child and Adolescent Psychiatry, University Medical Center Groningen, University of Groningen, P.O. Box 660, 9700 AR Groningen, The Netherlands. Tel.: +31 50 3681100; fax: +31 50 3681120.
E-mail addresses: A.Dietrich@med.umgc.nl, A.Dietrich@accare.nl (A. Dietrich).

0301-0511/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.biopsycho.2009.02.002

promote effective and flexible functioning to meet changing environmental demands (Beauchaine, 2001; Porges et al., 1994, 1996; Porges, 1995).

Baroreflex sensitivity (BRS), a measure of the quality of short-term blood pressure (BP) control that reflects the relationship between BP variability and HRV, has also been shown to be a useful indicator of autonomic function (Thayer and Brosschot, 2005; van Roon et al., 2004). BRS indicates the autonomic balance (i.e., reciprocal, dynamic relationship) between sympathetic and parasympathetic activity. Especially during rest, a high BRS points to a shift towards the latter, and is as such closely related to RSA. The autonomic flexibility–neurovisceral integration model, founded in polyvagal theory, suggests that high BRS reflects autonomic flexibility (i.e., the flexible regulation of autonomic balance), thus facilitating adaptability and health (Thayer and Brosschot, 2005; Thayer and Lane, 2000). In contrast, lower levels of vagal activity and reduced autonomic flexibility are assumed in relation to inhibition (Friedman, 2007).

To summarize, based on theoretical perspectives, temperamental activation is expected to be related to low HR and both high RSA (indicating high cardiac vagal activity) and high BRS (indicating flexible regulation of autonomic balance). Temperamental inhibition, in contrast, may be linked to high HR and both low RSA (indicating low cardiac vagal activity) and low BRS (indicating inflexible regulation of autonomic balance).

Despite some intriguing findings in favor of these theoretical assumptions, this field of research has been characterized by inconsistent results. While an association between temperamental activation and low HR has indeed been shown in a few pediatric and adult studies (Puttonen et al., 2008; Raine, 1996; Raine et al., 1997; Zuckerman, 1990), other reports (in adults) have suggested no association between both measures (Heponiemi et al., 2004; Keltikangas-Jarvinen et al., 1999; Knyazev et al., 2002). Increased resting RSA levels in infants, children, and adults with a high tendency to approach have indeed been suggested in some studies (Beauchaine, 2001; Puttonen et al., 2008; Richards and Cameron, 1989), but not all (Blair, 2003). Regarding BRS, we previously found a positive association with externalizing problems in girls (Dietrich et al., 2007), whereas the only other child study reported a lower BRS in impulsive boys (Allen et al., 2000).

With respect to inhibition, a number of studies have found increased HR at different ages (Garcia Coll et al., 1984; Kagan et al., 1987, 1988; Mezzacappa et al., 1997; Puttonen et al., 2008; Scarpa et al., 1997). There have, however, also been some negative studies in this respect, in children as well as in adults (Calkins and Fox, 1992; Heponiemi et al., 2004; Knyazev et al., 2002; Marshall and Stevenson-Hinde, 1998; Schmidt et al., 1999). A similar picture emerges for cardiac vagal activity. Whereas early studies have suggested lower vagal activity in inhibited young children (Garcia Coll et al., 1984; Reznick et al., 1986) and recently also in a population sample of adults (Puttonen et al., 2008), many other studies failed to find such a relationship (Brenner, 2005; Heponiemi et al., 2004; Hofmann et al., 2005; Knyazev et al., 2002; Marshall and Stevenson-Hinde, 1998; Movius and Allen, 2005; Ravaja, 2004; Schmidt et al., 1999). In our earlier study (Dietrich et al., 2007), we did not find an association between BRS and internalizing problems in preadolescents either.

The ambiguous findings regarding the relationship between autonomic function and temperamental activation and inhibition, and the paucity of studies in this area, especially regarding temperamental activation and BRS, highlight the need of further investigation of this subject (Fox et al., 2005; Marshall and Stevenson-Hinde, 2001). One explanation for the inconsistent findings may have been the use of small samples. Studying a large population sample offers the opportunity to reliably investigate these relationships, detect possible gender-specificity, and generalize findings to the general population.

In the present study, we investigated the possible relationship of high-intensity pleasure (as a specific example of temperamental activation) and shyness (as a specific example of temperamental inhibition) with resting HR, RSA, and BRS in a large population cohort of preadolescents. Typically, relations between temperament and autonomic function have focused on the early years of life (see Beauchaine, 2001). However, Rothbart and Derryberry (1981) used a more developmental framework of temperament in that it is shaped over time by an interplay between heredity, maturation, and experiences. This stresses the necessity of investigating temperament dimensions that are not limited to the first years of life.

We were specifically interested in high-intensity pleasure and shyness, as these traits have been shown to steer the conditional probability of externalizing and internalizing problems, thus functioning as direction markers (Oldehinkel et al., 2004). Additionally, we investigated autonomic reactions to orthostatic stress (standing), which have previously been related to psychological functioning (Kagan et al., 1994; Mezzacappa et al., 1997; Yeragani et al., 1991). We expected opposite autonomic patterns to be associated with high-intensity pleasure (i.e., low HR and both high RSA and BRS) versus shyness (i.e., high HR and both low RSA and BRS).

2. Methods

2.1. Participants

This study was performed in 938 10–13-year-old Dutch preadolescents (442 boys, mean 11.6 years, 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 been described earlier (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. There was no selective attrition in this subsample regarding temperament scores and general demographics.

The mean body mass index in the current sample was 18.9 ± 3.1 kg/m^2. 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 was reported by 0.6% of the participants, sometimes or a little bit by 5.7%, and (almost) never by 93.7%. Smoking tobacco regularly was reported by 0.2%, sometimes or a little bit by 2%, and (almost) never by 97.8%. The proportion of boys and girls in the prepubertal and pubertal phase was similar in both genders (Tanner stage 1: 32% and 29.8%, and stages 2–5: 68% and 70.2%, respectively; Tanner stage according to parental judgement). 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, 2007). Written informed consent was obtained from the preadolescents' parents, but participant's assent was not asked for, given their relatively young age. The study was approved by the National Dutch Medical Ethics Committee, in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

2.2. Measurements

2.2.1. Temperament

Temperament was assessed by parents' responses on the short form of the Early Adolescent Temperament Questionnaire Revised (EATQ-R; Hartman, 2000; Putnam et al., 2001). We included only those subscales of the EATQ-R that fitted to the two basic temperamental dimensions of activation and inhibition (Elliot and Thrash, 2002), and which steered the conditional probability of externalizing and internalizing problems, respectively (Oldehinkel et al., 2004). 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; six items, Cronbach's alpha 0.77) and shyness (i.e., behavioral inhibition to novelty and challenge, especially social; four 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, overall being similar to the original instrument (Oldehinkel et al., 2004; Putnam et al., 2001). We used the parent report, because of its better