Cardiac autonomic regulation and anger coping in adolescents

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ABSTRACT

The current study investigated spontaneous anger coping, cardiac autonomic regulation and phasic heart rate responses to anger provocation. Forty-five adolescents (27 female, mean age 14.7 years) attended the single experimental session, which included monitoring of continuous heart rate and blood pressure responses to anger provocation (receiving an unfair offer) using a modified version of the Ultimatum Game (UG). Vagal activation was operationalized as high frequency component of heart rate variability during rest periods, and spontaneous baroreflex-sensitivity (SBR) during the UG. Adolescents employing cognitive reappraisal showed higher vagal activity under resting conditions and attenuated heart rate deceleration after receiving the unfair offer compared with participants who tended to ruminate about their anger and experienced injustice. Results from SBR suggested vagal withdrawal in anger ruminators during contemplation of the unfair offer. These results provide further support for the specificity and sensitivity of vagal responses to higher cortical functions such as emotion regulation.

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1. Introduction

Anger is among the emotions elicited by conflicted interaction, perceived unfairness and blocked goals. Its experience and expression have been shown to represent a major public health concern for children and adolescents today. Prevalence reports show that anger-related problems such as oppositional behavior, verbal and physical aggression and violence are some of the more common reasons for children to be referred to mental health services (Nock et al., 2007).

The experience of anger and its expression in adolescents have also been linked to negative health outcomes through direct physiological pathways (Pajer, 2007). Although disease endpoints such as cardiovascular disorders do not usually become manifest until mid-life, some of the presumed processes linking negative emotions and physical disorders may well begin as early as adolescence. For example, a review of studies in youths (Grunbaum et al., 1997) found that hostility and anger are associated with high blood pressure, and results from more recent investigations are similar (Gump et al., 1999; Raikkönen et al., 2003).

Taken together these results suggest increased health risks for adolescents high in anger. Successful control of this emotion may, therefore, serve a health protective function, which may be of particular importance at a developmental age when negative emotions often first become problematic and the pathogenesis of cardiovascular disease appears to accelerate. Nevertheless, such control is often difficult to achieve, particularly for potent negative emotions such as anger (Gross et al., 2006). In this context two emotion regulation strategies have recently been investigated: expressive suppression and cognitive reappraisal (Gross, 2002). Expressive suppression aims at inhibiting ongoing emotion-expressive behavior and is considered a prototypical example of a response-focused emotion regulation strategy. Cognitive reappraisal, in contrast, is conceptualized as an antecedent-focused strategy: it aims at cognitively changing the interpretation of a situation such that the resulting emotion is modified, e.g. by construing a stressful situation as a challenge rather than a threat.

Previous studies in adults have shown that cognitive reappraisal, compared with no emotion regulation or response-focused emotion regulation, is associated with an adaptive profile of affective responding across a range of negative emotions including anger (Gross, 2001; Mauss et al., 2007). In our own studies investigating adolescents and young adults we consistently found the highest blood pressure reactivity to anger-provoking laboratory tasks in those employing response-focused emotion regulation (anger-

suppression) together with a family risk of essential hypertension (Vögele and Steptoe, 1992, 1993; Vögele et al., 1997; Vögele, 2002).

Nevertheless, several issues in the existing literature remain. Firstly, most experimental studies investigating the effects of emotion regulation strategies such as anger reappraisal and its physiological concomitants focus on adults, although prevention interventions would particularly benefit from results in adolescents. Secondly, few studies have used ecologically valid emotional situations, relying mostly on passive slide or film viewing. Thirdly, studies tended to either experimentally manipulate emotion regulation or relied on measuring trait emotion regulation by using self-report questionnaires. We are aware of only one report of a series of studies (Egloff et al., 2006) that investigated spontaneous emotion regulation, i.e. naturally occurring emotion regulation strategies in an experimental context. The present study was designed to address these issues by investigating the effects of spontaneous emotion regulation on psychophysiological and psychological responses to an ecologically valid anger-provoking situation in adolescents.

Psychophysiological responses to emotional stimuli have mostly been investigated in terms of cardiovascular reactivity and orienting and/or defense reactions. Previous studies have mostly used visual stimuli of different affective values and found a marked cardiac deceleration in response to viewing unpleasant pictures (e.g. Sánchez-Navarro et al., 2006). In the current study we wanted to address the question whether an ecologically more valid stressor would provoke a similar response pattern, and whether this is affected by emotion regulation strategies.

A fourth issue we wanted to address concerns the central nervous system processes (e.g. executive function, inhibition) and their associated neural networks that are presumed to be involved in emotion regulation. There is recent evidence that adolescence is a particularly sensitive period for the development of the prefrontal cortex (PFC) and the associated development of social-cognitive functions (Blakemore, 2008; Casey et al., 2008). Taken together these findings suggest a central role of executive functions such as inhibition in emotion regulation. Hoeksma et al. (2004), for example, investigated this hypothesis in a small observational study by studying the association between children's inhibitory control as indexed by their performance in a Stop Signal Paradigm (Logan, 1994) and emotion regulation capacity operationalized as anger variability over 3–4 days. The results show a moderate to strong relationship between the stop signal reaction time and the mean standard deviation of anger variability and confirm the notion that response inhibition affects the regulation of anger.

Inhibitory control and emotion regulation have been closely linked to a peripheral physiological parameter, i.e. heart rate variability (HRV) as an indicator of cardiac autonomic regulation (Appelhans and Luecken, 2006). Low vagal activation (low HRV) has been shown to be associated with hyper vigilance and the activation of a defensive behavioral system in response to non-threatening stimuli while high vagal activity (high HRV) was related to the most differentiated emotion-modulated response (Ruiz-Padial et al., 2003). In support of the notion of an association between HRV and emotion regulation capacity, Pu et al. (2010) have recently shown that respiratory sinus arrhythmia (RSA) as a measure of cardiac vagal tone modulated the facial expression of negative emotions in that those with high RSA showed less but reported feeling just as much negative emotions as those with low RSA. Further evidence for low HRV as an index of disinhibition and affective dysregulation comes from studies in psychopathology, which generally find low HRV to be associated with disorders such as depression and general anxiety disorder (Friedman, 2007) and post-traumatic stress disorder (Blechert et al., 2007). In this context we hypothesized that adolescents using cognitive reappraisal to be characterized by HRV suggesting increased vagal activity and a less

marked cardiac deceleration to anger provocation when compared with participants emphasizing the experienced injustice.

2. Materials and methods

2.1. Participant recruitment and sample description

Adolescent volunteers were recruited from a secondary school. A written description was provided to students and their parents or legal carers about study aims and procedures. Participating volunteers and their parents or legal carers provided written informed consent. Exclusion criteria were self-reported chronic physical or mental health conditions (e.g. bronchial asthma, cardiovascular disorders, depression) or current acute illnesses (e.g. cold) and medication with known effects on the autonomic nervous system. The study received approval from the head teacher of the participating school and ethical approval from the local education authority ("Schulamt"). All students were paid an initial €5,- for participation. In addition, participants received the total earned in the Ultimatum Game. The total sample included 45 adolescent students (27 female) with a mean age of 14.7 years ($SD = .80$).

2.2. Experimental task

In the current study we used an adaptation of the Ultimatum Game (UG) to induce feelings of anger. In the UG, two players are provided with an endowment, e.g. a sum of money. One player (proposer) makes an offer to split the money, which the other player (responder) may accept or reject. If the responder accepts the offer, both players are paid accordingly. If the responder rejects the offer, neither player is paid (Thaler, 1988). According to a model by Straub and Murnighan (1995) an offer that is perceived as unfair leads to feelings of anger and spiteful rejection of the offer by the respondent, even if this means (avoidable) financial loss. There is empirical support for this model and results show that rejections are most frequent and anger is most intense when respondents can evaluate the unfairness of the offer and attribute responsibility to the proposer (Pilluta and Murnighan, 1996; Sanfey et al., 2003; Tabibnia et al., 2008; van't Wout et al., 2006).

In order to increase the perception of unfairness we adapted the UG by introducing two rounds: in round 1 the study participant took the role of proposer, in round 2 that of responder. The co-player was virtual only and simulated by a computer program. In order to enhance the personal meaning of the offer and facilitate attribution of responsibility to another person experimental participants were told that their co-player was sitting in a room next door and that they could communicate via a personal computer to submit and receive offers. Participants were told that their decision would be implemented, such that they and the co-player would be paid accordingly. In round 1 (€10,-) the offer of the participant ($M = €4,80.-, SD = €0,80.-$) was always accepted by the virtual co-player. The majority of participants offered a fair share of €5,- (74.5%) or €4,- (11.8%), which is a typical finding in research using the UG (Nowak et al., 2000). The three participants who offered €3,- or less were excluded from the analysis, as for these individuals a subsequent low offer by the virtual co-player would not have violated the norm of reciprocity. In round 2 (€10,-) the virtual co-player made an extremely unfair offer (€1 out of €10), thereby violating the norm of reciprocity. A statement, which was designed to increase feelings of anger, followed this offer: "I know you would have liked more, but that's the way it goes. Take it or leave it!". This period is referred to as provocation in the following sections. Participants were asked to contemplate this offer for one minute before responding by keystroke (referred to as contemplation), which ended the UG. Sixty-five percent of participants rejected the offer. The total time that elapsed between receiving the offer and the end of the UG was 76 s. All UG instructions, the offer and the statement were communicated via computer screen, and participants were instructed to respond by pressing assigned keys on the keyboard. Both the offer and the statement remained on screen for 8 s each. Both rounds of the UG were identical in procedure and timeline, except for the statement, which was only presented to the participant in round 2.

2.3. Equipment and measures

The experimental sessions were conducted in a light- and temperature-controlled laboratory. The electrocardiogram was recorded at a 256 Hz sample rate using disposable electrodes attached in the lead II configuration. Outliers were identified based on an algorithm described by Berntson et al. (1990) and edited manually. A continuous arterial blood pressure waveform was obtained non-invasively by tonometry (BP-508 type S, Colin Medical Technology Corporation, Bad Hersfeld, Germany) with the tonometry sensor attached over the left radial artery and sampled at 4000 Hz. Beat-by-beat systolic (SBP) and diastolic blood pressure values (DBP) were identified as local maxima/minima in the arterial pressure waveform and manually edited. Heart rate (HR) measured in beats-per-minute (bpm), inter-beat-interval (IBI) in ms, and SBP and DBP in mmHg were stored digitally on the recording device for later analysis.

During the experimental sessions participants were asked to rate their current experience of anger and happiness by giving a number between 0 (not at all) and 100 (extremely) after baseline and after completing the UG trial. Following the UG trial participants were also asked to retrospectively indicate their mood when receiving