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Cardiac reactivity to and recovery from acute stress: Temporal associations with implicit anxiety

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ABSTRACT

Excessive cardiac responses to stressful events are a risk factor for morbidity and mortality. Adverse cardiac responses are usually attributed to conscious negative stress and emotions. Yet, cardiac responses might also be affected by emotions that are not consciously reported. Here we tested this hypothesis. Sixty participants were randomly allocated to an evaluated speaking stressor or control condition. Trait, state and implicit anxiety were assessed with the State Trait Anxiety Inventory, visual analog scales and the Implicit Association Test for assessing anxiety, with the latter two assessed before and after the stressor. Results showed that the stressor did not significantly affect implicit anxiety. Yet, participants with high implicit anxiety after the stressor had an overall enhanced heart rate and larger stressor-induced decreases in heart rate variability. These associations were independent of conscious anxiety. The implications of the results for a better understanding of excessive cardiac activity are discussed.

1. Introduction

Anxiety has been associated with an increased risk of cardiovascular morbidity and mortality (Friedman, 2007). In a recent meta-analysis, anxiety was found to be a risk factor for coronary heart disease and cardiac death in initially healthy people (Roest et al., 2010). In establishing a link between anxiety and cardiovascular activity, researchers usually focus on the link between consciously reported emotions (self-reports) and health outcomes. For example, people who frequently report feelings of anxiety and worries show enhanced cardiovascular responses to stressful events and recover more slowly from these events (Shinba et al., 2008; Verkuil et al., 2009b). When stress-related cardiovascular activity is excessive and prolonged this contributes to the total 'wear and tear' effects that stressors have on the human body, eventually leading to health problems (McEwen, 2003; Pieper and Brosschot, 2005).

In recent years, several authors have suggested that cardiovascular health is not only determined by people's tendencies to consciously experience feelings of anxiety and worries, but also by processes that people are not consciously aware of (Brosschot et al., 2010; Gendolla, 2012), possibly because they are not able or willing to report on those negative feelings (Lane, 2008; Scherer, 2005). We know that a lot of information processing occurs without us being aware of it (Bargh and Morsella, 2008), and this might be true for stress-related information as well (Brosschot, 2010). For example, patients suffering from anxiety disorders are known to suffer from implicit biases in the processing of anxiety-related information (Bar-Haim et al., 2007; Mitte, 2008). Furthermore, these patients have strong implicit associations between their self-schemata and fear related information (Glashouwer and De Jong, 2010). These implicit processes are believed to maintain the anxiety (Glashouwer et al., 2012). It is also possible that these anxiety-related implicit processes could partially explain the extent and duration of the cardiovascular response to stressful events (Brosschot et al., 2010). As such, implicit biases could possibly account for a part of the cardiovascular risks of anxiety disorders.

Research into the cardiovascular effects of implicit biases is still preliminary. Several subliminal priming studies suggest that unconscious information can enhance cardiovascular reactivity (Gendolla, 2012; Hull et al., 2002; Levy et al., 2000; Silvestrini and Gendolla, 2011). Only a few studies have examined the effectiveness of implicit measures of emotions in predicting cardiovascular responses to a stressful event. For example, heightened cardiovascular reactivity to stressful events has been linked to attention that is biased towards threat (Egloff et al., 2002; Gump and Matthews, 1998) and to implicit stressor-related cognitions assessed with Implicit Association Tests (IATs; Nausheen et al., 2007; Van Bockstaele et al., 2011). In contrast, we previously did not find a significant association between implicit stress – assessed with a modified lexical decision task – and slowed cardiac recovery from a

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stressor (Verkuil et al., 2009b). Hitherto, these previous studies did not address whether all the cardiovascular changes that are observed during stressful events (reactivity as well as recovery) are actually accompanied by changes in implicit measures, or whether these changes are only *predicted* by single assessments of these implicit measures. In the present study we therefore aimed to clarify this issue by testing the associations between implicit anxiety before and after a stressor as measured with the IAT and cardiac activity before, during and after a stressor.

In line with previous studies and in line with what we suggested in our theoretical paper on this issue (Brosschot et al., 2010), we now used the Implicit Association Test to assess implicit anxiety. Specifically, we used the IAT version that assesses anxiety, the IAT—Anxiety (Egloff and Schmukle, 2002). This test measures the extent to which people associate words related to 'the self' (I, myself) with words expressing either anxiety or calmness. The IAT—Anxiety (Schmukle and Egloff, 2005) as well as the IAT—Depression (Creemers et al., 2013) appeared to be able to capture state effects in respectively implicit anxiety and implicit depression. However, in an initial validation study, IAT—Anxiety scores did not change in response to a speech anticipation manipulation (Schmukle and Egloff, 2004), suggesting that it mainly taps into the trait component. On the other hand, the IAT—Anxiety in that study was only administered during anticipation and not after the speech stressor had ended, nor it has been administered after any other stressors. We therefore decided to administer the IAT—Anxiety not only during the anticipation of a stressful event (giving a speech) but also after this stressor had ended. Thus, we examined whether the IATs could capture the activation of associations between "I" and "anxiety" due to the stressor and whether this state implicit anxiety was associated with the physiological responses to this stressor.

As physiological marker of stress, heart rate (HR) and heart rate variability (HRV) were used, both of which are independent markers of cardiovascular health risks (Hillebrand et al., 2013; Thayer and Lane, 2007). Particularly, people who show heightened HR(V) responses to stress and impaired post-stress recovery are at increased risk of cardiovascular problems (Chida and Steptoe, 2010; Steptoe and Marmot, 2005). HR is partially determined by the interplay between the sympathetic and parasympathetic branches of the autonomic nervous system (Thayer et al., 2010). In contrast to HR, HRV – when determined as the beat-to-beat variability in a series of beats – is specifically influenced by parasympathetic (vagus nerve) activity, because the sympathetic influence on the heart is too slow to cause these quick changes. Importantly, slow HR recovery has also been shown to be due to parasympathetic activity, more than high sympathetic activity (Imai et al., 1994). Because stress has well known effects on both the sympathetic and the parasympathetic nervous system, we expected that both HR and HRV would be affected by the induction of stress and that the magnitude of the changes in HR(V) would be associated with implicit anxiety.

In sum, our hypotheses were that: (1) implicit anxiety and HR would be increased and HRV decreased in anticipation of, during and after the speech stressor; that (2) anticipatory HR and HRV responses to the stressor would be correlated to anticipatory implicit anxiety, and that (3) HR and HRV responses during and after the stressor would be correlated with implicit anxiety after the stressor. The effects of implicit anxiety were expected to occur independent of those of explicit anxiety.

2. Method

2.1. Participants

Sixty first year students (41 women) were recruited at Leiden University. These students were randomly allocated to one of the two conditions, the control and the experimental (stress induction) condition. The mean age of the sample was 22.38 years ($SD = 3.27$), and there were no differences in age ($t(58) = 0.826$, $p = .412$) or gender ($\chi^2 = 1.93$, $p = .27$) between the groups (control = 18 women, stress induction = 23 women). Participants were free from cardiovascular diseases. Chi-square tests showed that instances of current (N = 3) and past psychiatric history (N = 10) did not differ between the groups ($ps > .10$). One participant in the control group was taking antidepressant medication, excluding this participant from the analyses did not change the results, therefore the results for the total sample are reported. Upon entering the laboratory, participants were given a brief explanation of the purpose of the experiment and provided their consent. The study was approved by the Institutional Reviewing Board.

2.2. Instruments

2.2.1. Cardiac activity

Heart rate (bpm) and the root mean square of successive differences of interbeat intervals (RMSSD; ms) were used as indices of cardiac activity. Cardiac interbeat intervals (IBIs) were continuously measured, in a non-invasive manner, with a Polar s810i wristwatch and the Polar WearLink 31 belt, which has a sampling rate of 1000 Hz (Polar Electro Nederland BV; Gamelin et al., 2006). The IBIs were preprocessed for artifacts using the automated algorithm provided by the Polar Precision Software. The corrected IBI series were subsequently processed with the HRV analysis program, using the smoothness prior based approach which removes the low frequency trend component of the IBIs (Niskanen et al., 2004). Each phase of the experiment (baseline, IATs, speech anticipation, speech task and recovery; see below for more details) was split into two epochs, and the mean HR and mean RMSSD were calculated for each epoch, with each epoch lasting 2.5 min.

2.2.2. Implicit anxiety

Implicit anxiety was measured with the IAT—Anxiety. The task was adapted from Egloff and Schmukle (2002). The target categories we used were '*self*' (me, my, own, I, self) and '*others*' (they, them, their, her, others), and the attribute categories were '*anxiety*' (nervous, afraid, fearful, anxious, uncertain) and '*calmness*' (relaxed, balanced, at ease, calm, restful). The stimulus-words used for the 'self', 'anxiety' and 'calmness' categories were borrowed from Egloff and Schmukle (2002). We slightly adapted the words used by Egloff and Schmukle (2002) for the 'others' category. The reason is that some of the words that they used referred to the second person (e.g., 'you', 'your'), and we considered these words to be ambiguous, as the participants might erroneously assume that the words 'you' and 'your' were referring to themselves.

To perform the task, participants were asked to categorize stimulus-words into two categories (self versus others; anxiety versus calmness, or a combination of these categories) by pressing a key on the keyboard (the letter Q or P, each indicating a category). The IAT procedure consisted of 5 blocks. In the first block, participants practiced the discrimination of self and other stimulus-words (target discrimination) during 20 trials (each item was presented twice). In blocks 2 and 4, the participants sorted stimulus-words into the anxiety or calmness category (attribute discrimination), with a switched key assignment in Block 4 (20 trials per block). The critical Blocks 3 and 5 consisted of 20 practice trials and 60 critical trials. In these trials, participants categorized stimulus-words into categories that were now a combination of an attribute (e.g., anxiety) and a target (e.g., self), assigned to the same key.

Response latencies on the critical trials were transformed into implicit anxiety indices by using the algorithm provided by Greenwald et al. (2003). Higher scores on this index reflect higher levels of implicit anxiety.

2.2.3. Trait anxiety

To measure trait anxiety we administered the trait version of the State Trait Anxiety Inventory (STAI-T; Dutch version: van der Ploeg et al., 1980). It consists of 20 self-report items and earlier use has shown good internal consistency and validity (van der Ploeg et al., 1980).