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Sigh rate and respiratory variability during normal breathing and the role of negative affectivity

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ABSTRACT

Spontaneous breathing was measured in healthy persons scoring either high ($N=45$) or low ($N=30$) on trait negative affectivity (NA), during a 10 min period of quiet sitting using the LifeShirt System®. Sighing and respiratory variability before and after sighs were assessed. Total respiratory variability of minute ventilation was indexed by the coefficient of variation and structured (correlated) variability was quantified by the autocorrelation. Total variability was higher before a sigh than before a non-sigh, without concomitant differences in structured variability, suggesting more random variability before a sigh. After a sigh, correlated variability increased whereas it remained the same after a non-sigh. Thus sighing acted as a resetter of the respiratory system. However, when comparing the low and the high NA group, this pattern was specific for high NA individuals. We conclude that it is important to take into account individual difference variables when studying the psychophysiological functions of sighing.

1. Introduction

Healthy breathing patterns are characterized by considerable variability (Bruce, and Daubenspeck, 1995; Donaldson, 1992; Hughson et al., 1995; Small et al., 1999; Tobin et al., 1995; Wysocki et al., 2006), which can be linked to various sources. External (e.g. behavioral) stimulations may cause random variability, which allows the respiratory system to react sensitively to changing environmental demands. On the other hand, in order to return to or maintain a dynamic steady state, homeostatic control processes are activated to induce structured, correlated breath-to-breath variability (Berntson, and Cacioppo, 2000). Deviations from the equilibrium between correlated and random variability reduce homeostatic capacity and system sensitivity: either too much randomness or a lack of structured variability can contribute to system irregularities. Vlemincx et al. (2010b) recently put forward the hypothesis that, in case of imbalance, sighing acts as a resetter of the respiratory system to restore healthy variability. They showed that total variability in normal breathing increases towards a sigh and that, after a sigh, correlated variability increases. In breathing periods without sighs, no such changes could be detected (Vlemincx et al., 2010b). This suggests that a sigh resets structured, correlated respiratory variability in healthy subjects. A first aim of the present study was to replicate this finding.

The resetter account (Vlemincx et al., 2010b) may help to explain why an increased sigh rate is associated with aversive psychological states that are characterized by excessive random variability, such as mental stress (Soltysik and Jelen, 2005; Vlemincx et al., 2009, 2010a) and negative affect (McClernon et al., 2004). In line with this account, it is reasonable to hypothesize that such effects are more pronounced in persons who tend to experience more stress and negative affect. In this study, we therefore investigated the relationship between sighing, respiratory variability and negative affectivity (NA) during passive sitting which served as an extensive baseline for another study on the relationship between NA and symptom reporting. We expected: (1) sigh frequency to be higher for people high in NA as compared to low NA people; (2) total respiratory variability to be higher before a sigh than before a 'non-sigh' and an increase in correlated variability after a sigh; and (3) the latter differences to be more pronounced in the high NA group compared to the low NA group.

2. Method

2.1. Participants

Seventy-five female psychology undergraduates (mean age 20.1 years, range 18–26) were selected from a group of potential participants who were recruited through advertisements posted on an electronic message board in the Department of Psychology of the University of Leuven, Belgium. None of them suffered from any cardiovascular or pulmonary disease, nor reported any other health problems. All participants were paid 20 Euro or given course credits in exchange for participation.

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2.2. Measures

Only the variables relevant for the present purposes will be described.

2.2.1. Questionnaire

Based on the trait version of the Positive and Negative Affect Schedule (PANAS), participants scoring either low or high on NA were selected. The NA scale of the trait version of the PANAS consists of 10 negative adjectives for which participants have to indicate (on a five-point rating scale) to which extent they feel that way in general. The reliability and construct validity of the PANAS have been documented elsewhere (Engelen et al., 2006; Watson et al., 1998). Based on a pilot study with 394 female students, cut-off scores were determined by calculating the upper and lower quartiles and identifying the most extreme groups. In that way, participants were categorized as either low NA (NA score <21) or high NA (NA score >29). Earlier studies showed a good discriminative power of these cut-off scores (Bogaerts et al., 2008, 2010a, 2010b). For the purpose of the present study, a low NA group ($N=30$, mean age 21.1 years, range 18–26) was compared with a high NA group ($N=45$, mean age 19.4 years, range 18–24).

2.2.2. Respiratory measures

Breathing behavior was measured non-invasively by means of respiratory inductive plethysmography (RIP) (LifeShirt System®, Vivometrics Inc., Ventura, CA). Motion and posture were assessed by the LifeShirt accelerometers, which allowed control for movement artifacts. Raw respiratory data were edited by means of dedicated Vivologic software (Vivometrics Inc., Ventura, CA; for more details, see Vlemincx et al., 2010b). All signals were plotted as a function of time and visually inspected to eliminate technical abnormalities, but none was found. Movement artifacts were controlled for by evaluating the accelerometer signals: all participants maintained the same posture during the baseline period, as indicated by a mean motion value of 2.02, with a range of 0–4.34 on a scale from 0 (no movement at all) to 5 (resting) to 15 (walking) to 50 (running fast). Next, respiratory parameters (inspiratory volume (V′i), respiration rate (RR = 60/total breath time) and minute ventilation ($V'e = V'i \times RR$)) were calculated breath by breath. The number of sighs was calculated for the 10 min baseline period. A sigh was defined as a breath with an inspiratory volume at least twice as large as the mean inspiratory volume during this phase.

2.3. Procedure

Students who expressed interest in participating based on the advertisement were sent the PANAS-TRAIT questionnaire to fill out. When their scores exceeded the predefined cut-offs, they were told that they were invited to take part in an experiment to test a new ambulatory measurement instrument. Sighing was not mentioned. All participants were tested individually. Upon arrival they were put on the LifeShirt garment and all sensors were connected to the LifeShirt recorder. A 10 min baseline registration followed, that preceded the actual experiment. Participants were explicitly instructed not to speak and to sit comfortably but motionless during the recording. The data analysis and results reported here, apply to the baseline registration only. Informed consent was obtained from all participants and the study was approved by the Ethics Committee of the Department of Psychology.

2.4. Data analysis

2.4.1. Respiratory variability preceding and following sighs and non-sighs

In accordance with Vlemincx et al. (2010b), up to four blocks preceding and following sighs were defined. Each block consisted of 10 breaths. Between blocks there was a 50% window overlap, so that the last five breaths of a block also were the first five breaths of the next block. This window overlap allows to look at more gradual changes in respiratory dynamics. Fig. 1 (Vlemincx et al., 2010b) gives a schematic representation of block allocation. Sigh series was created consisting of a sigh and as many (up to four) 10-breath blocks as possible preceding (pre-blocks) and following each sigh (post-blocks). Across participants, on average 3.30 (range 1–4) blocks preceding sighs and 3.11 (range 1–4) blocks following sighs could be composed. Whenever possible, complete non-sigh series (four pre-blocks, a non-sigh and four post-blocks) were created in the remainder of the data. In total, 124 sigh series and 111 complete non-sigh series could be created. For 21 subjects, no non-sigh series could be created (low NA, $N=10$; high NA, $N=11$), whereas 27 subjects did not sigh (low NA, $N=10$; high NA, $N=17$). Total respiratory variability and correlated respiratory variability in minute ventilation (V′e) were quantified as the coefficient of variation ($CV = (SD/mean) * 100$) and autocorrelation at one breath lag (AR) of V′e. AR is calculated as the correlation between a string of 10 consecutive breaths (block) and itself, shifted one breath. Both measures of respiratory variability were calculated for each group and for each block. The focus on V′e arises from the reasoning that the major function of breathing is gas exchange with the environment in proportion to metabolic needs. In young healthy persons, normal gas tensions (PO_2 and PCO_2) are maintained by continuously adjusting frequency and volume characteristics of the airflow. Because individuals are different in lung capacity and in propensity to rely on frequency or volume, minute ventilation V′e which combines both time and volume parameters into a single measure is a more consistent indicator of breathing behavior to maintain normal gas exchange (George and Kinasewitz, 2005).

2.4.2. Statistical analysis

Basic respiratory parameters, sigh frequency, CV(V′e) and AR(V′e) were subjected to one-way ANOVAs with 'group' (low vs. high NA) as between-subject variable. CV(V′e) and AR(V′e) were calculated for each block for each series and subjected to (1) a mixed model analysis with series (sigh vs. non-sigh), time (pre vs. post) and blocks (block 1 to block 4) as fixed categorical predictors and (2) to a mixed model analysis with series, time, blocks and the group (low vs. high NA) factor also included. Planned comparisons were used to test differences in CV(V′e) and AR(V′e) between pre-block 4 of sigh- and non-sigh series and between pre-block 4 and post-block 1 for both sigh and non-sigh series. Bonferonni-corrected p-values are reported. Planned comparisons were considered significant at

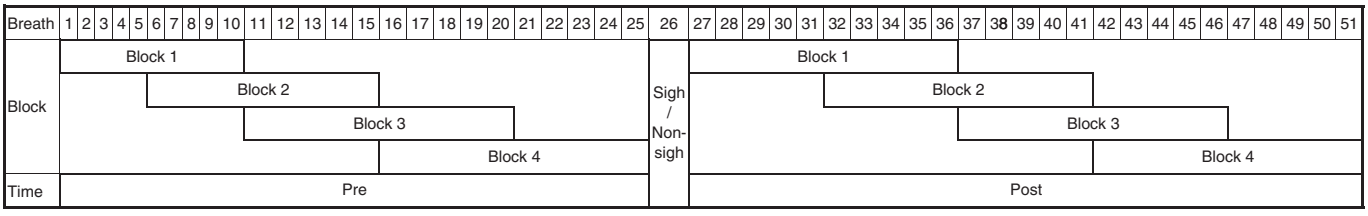

Fig. 1. Schematic illustration of block allocation.