Association between Attention and Heart Rate Fluctuations in Pathological Worriers

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Recent data suggests that several psychopathological conditions are associated with alterations in the variability of behavioral and physiological responses. Pathological worry, defined as the cognitive representation of a potential threat, has been associated with reduced variability of heart beat oscillations (i.e., decreased heart rate variability; HRV) and lapses of attention indexed by reaction times (RTs). Clinical populations with attention deficit show RTs oscillation around 0.05 and 0.01 Hz when performing a sustained attention task. We tested the hypothesis that people who are prone to worry do it in a predictable oscillating pattern revealed through recurrent lapses in attention and concomitant oscillating HRV. Sixty healthy young adults (50% women) were recruited: 30 exceeded the clinical cut-off on the Penn State Worry Questionnaire (PSWQ; High-Worry, HW); the remaining 30 constituted

the Low-Worry (LW) group. After a diagnostic assessment, participants performed two 15-min sustained attention tasks, interspersed by a standardized worry-induction procedure. RTs, HRV and moods were assessed. The analyses of the frequency spectrum showed that the HW group presents a significant higher and constant peak of RTs oscillation around 0.01 Hz (period 100 s) after the induction of worry, in comparison with their baseline and with the LW group that was not responsive to the induction procedure. Physiologically, the induction significantly reduced high-frequency HRV and such reduction was associated with levels of self-reported worry. Results are coherent with the oscillatory nature of the default mode network (DMN) and further confirm an association between cognitive rigidity and autonomic nervous system inflexibility.

Introduction

Excessive worry is a core symptom of generalized anxiety disorder (GAD; DSM-V) and has been conceptualized as a chain of thoughts and images, negatively affect-laden and relatively uncontrollable, containing the possibility of one or more negative outcomes and closely related to the fear process (Borkovec et al., 1983). However, worry is definitely not restricted to psychopathology, in fact it can be extremely pervasive also in people who do not meet a former diagnosis of GAD (Ruscio et al., 2001). In this context, the Penn State Worry Questionnaire (PSWQ; Meyer et al., 1990) is a reliable screening measure for pathological worry in GAD and in non-pathological individuals (Beck et al., 1995).

Pathological worry has been associated with several dysfunctional

consequences both at a somatic level (chronic physiological activation; Brosschot et al., 2006) and at a cognitive level (impoverished sustained attention; Rapee, 1993). For instance, when given instructions to actively worry about a personally relevant topic, individuals with high levels of self-reported worry report more negative thought intrusions during an attention focusing task compared with those with low levels of self-reported worry (Borkovec et al., 1983). Consistently, Hayes et al. (2008) have shown that—compared with thinking about other topics—worry depletes the ability to exert attentional control, particularly in pathological worriers. Moreover, Fox et al. (2015) showed that dispositional differences in trait propensity to worry are related to difficulties in ignoring irrelevant material with a significant correlation between the degree of deficit in attentional control and the degree of difficulty in suppressing negative thought intrusions. Ottaviani et al. (2013, 2016b) confirmed that a worry induction is associated with a slowing down in reaction times (RTs) during a sustained attention task, further revealing an association between such attentional/cognitive rigidity and autonomic inflexibility, indexed by reduced heart rate variability (HRV). This association has been demonstrated using both subjective measures of cognitive rigidity (Ottaviani et al., 2013) and neural markers of attentional capacity (Ottaviani et al., 2016b). As to the latter, results indicated an association between difficulties in inhibiting worrisome thoughts (both subjectively reported and indexed by RTs slowing down) and impaired deactivation of areas belonging to the so-called default mode network (DMN; Ottaviani et al., 2016b).

The DMN activates during resting states, i.e., when the individual is awake but not actively engaged and the mind is free to wander (Northoff and Bermpohl, 2004; Doucet et al., 2011, 2012). Previous electroencephalography (EEG)- and functional magnetic resonance imaging (fMRI)-based studies identified the low frequency range (0.01–0.1 Hz) as the range within which the

DMN pulses (Buzsáki and Draguhn, 2004; De Luca et al., 2006; Balduzzi et al., 2008; Helps et al., 2008; Knyazev et al., 2011; Doucet et al., 2012). According to the Default Mode Interference Hypothesis (Sonuga-Barke and Castellanos, 2007), DMN deactivation would never be complete in the presence of attention deficits; instead, the DMN would intrude during the execution of active tasks, causing lapses in attention (Weissman et al., 2006).

Rather than being random, the attentional falls follow a periodic pattern and the frequency of such lapses in attention is likely to follow the intrinsic frequency of DMN activation. For example, recent studies using time-frequency analysis (e.g., fast Fourier or wavelet transform) in children with Attention-Deficit/Hyperactivity Disorder (ADHD) reported peculiar RTs oscillations around a peak of 0.05 Hz, indicating lapses in attention occurring about every 20 s (Castellanos et al., 2005). Besides, this oscillation pattern proved to be a good predictor of ADHD diagnosis (Di Martino et al., 2008). Subsequent studies on ADHD mostly employed flanker tasks or sustained attention tasks and consistently found significant oscillation peaks in the very low frequency range (0.027–0.073 Hz; Johnson et al., 2007a,b; Di Martino et al., 2008; Adamo et al., 2014).

The Default Mode Interference Hypothesis has also been used as a plausible explanation for the sustained attention deficit of young patients with frontal lesions after traumatic brain injury (Gazzellini et al., 2016). Gazzellini et al. (2016) applied continuous wavelet transform (CWT) to RTs and theta/beta (qEEG) time series. In order to enhance sensitivity in the low-frequency range, attentional tasks duration was kept longer (up to 15–19 min) compared to that used in previous studies. Results showed significant high-power oscillations around 0.01 Hz in traumatic brain injury patients' performance but not in that of controls for both RTs and theta/beta time series. Results from this and the above-mentioned ADHD studies seem to suggest that very low-frequency oscillation of RTs is a transdiagnostic feature

linked to sustained attention deficits irrespective of the underlying specific pathological condition. Indeed, a general increase in RTs variability during attention demanding tasks has been considered as a behavioral biomarker of several psychopathological and neurological conditions (e.g., in bipolar disorder, schizophrenia, ADHD, traumatic brain injury, neurodegenerative pathologies), even in the absence of differences with healthy controls in terms of mean RTs (for a review, see MacDonald et al., 2006).

The main aim of the present study is to determine whether persons who are highly prone to engage in worrisome thoughts do it in a predictable oscillating pattern revealed through increased RTs variability, recurrent lapses in attention, and concomitant oscillating Heart Rate (HR). Such a pattern would be consistent with the hypothesis of a recurrent and intrusive DMN activation during goal-oriented activity (externally directed cognition; Dixon et al., 2014) and the related failure in deactivating such midline structures activity. Given the previously reported association between autonomic and cognitive rigidity, we hypothesize that High-Worry (HW) individuals would show a distinctive pattern of low-frequency spectral power (around 0.01–0.05 Hz) in both HRV and RTs time series, revealing lapses in attention during the execution of a sustained attention task. Lastly, we hypothesized these oscillatory patterns to be associated with state and trait psychological characteristics of the individual.

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