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# Openness to experience and aesthetic chills: Links to heart rate sympathetic activity

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ABSTRACT

Openness to experience has important links to cognitive processes such as creativity, and to values, such as political attitudes. The biological origins of variation in openness to experience are, however, obscure. The centrality of "aesthetic chills" to high openness suggests that sympathetic nervous system activation may play a role. Here, we tested this using the low-frequency heart rate variability power measure (LF) as biomarker of sympathetic activation, tested under baseline and stress conditions in a sample of 952 subjects, and controlling for measured confounders of age, sex, height, weight and BMI. A significant association was found between LF and openness to experience ($\beta = 0.10$, 95% CI [0.02, 0.17], $p < .01$). These results suggest links between openness to experience and sympathetic nervous system activity explaining, at least in part, relationships of openness to such traits as aesthetic chills.



## 1. Introduction

Openness to experience is one of a small number of basic domains of human personality (McCrae & Sutin, 2009). Understanding the mechanisms of variation in openness to experience is of value in understanding its diverse correlates, which range from creativity (McCrae, 1987) to political ideology and values (Lewis & Bates, 2011). Openness to experience should also be associated with specific neural activity to account for that part of individual differences in trait levels which reflects biological function. Here we test the hypothesis that higher levels of openness to experience are reflected in increased autonomic activity, a potential biomarker for further research on the mechanisms of openness to experience. We begin by briefly reviewing the idea that differences in reward/motivation underlie openness.

In their review of the empirical literature on openness to experience, McCrae and Costa (1997) argue that while it is correlated with higher education and with IQ (e.g. Silvia & Sanders, 2010), openness to experience cannot be understood as a cognitive ability or as an acculturated value-set but is, rather, a distinct multi-faceted motivational system affecting the "*breadth, depth, and permeability of consciousness, and in the recurrent need to enlarge and examine experience*" (McCrae & Costa, 1997, p. 826). Such descriptors, they acknowledge, while they capture the experience of openness, require greater specification and mechanistic explication to form a theory. In particular, McCrae and Costa (1997) suggest that the neural correlates of openness to experience could be differences in brain regions underpinning reward/motivational structures.

One clue to the nature of potential biological links underlying openness to experience was highlighted by McCrae (2007), who reported that the single best marker of openness to experience, irrespective of culture examined was the experience of "*aesthetic chills*" defined as "*a transient emotional response to music or other experiences of beauty*" formed. Self-reported aesthetic chills, may, then, provide a behavioral marker of the biological functions underlying openness. Such biological functions that might in turn be objectively measured.

One possible systematic difference in motivation that could support openness to experience is alterations to sympathetic autonomic "fight or flight" functions: High openness to experience could plausibly be linked to alterations in autonomic responding promoting prolonged absorption in stimuli. In line with this, Blood and Zatorre (2001) reported a monotonic relationship of cerebral blood flow changes correlated with the intensity of aesthetic chills, regionalized the ventral striatum, midbrain, amygdala, orbito-frontal cortex, and ventral medial prefrontal cortex. Each of these areas is associated with reward/motivation, emotion, and arousal. These brain functional changes were accompanied by similar dose-dependent changes in heart rate, electromyogram, and respiration. Thus, the results of Blood and Zatorre (2001) indicate that openness to experience is associated with alterations in heart rate,

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mediated by specific regional reward/motivation brain activation. Based on these results, in the present paper, we tentatively explored the hypothesis that heart rate activity indices linked to sympathetic autonomic activation that is reflected in cardiovascular function might provide an easily measured biomarker of openness to experience.

The most specific measure of sympathetic activity accessible from heart rate measures is the low-frequency (LF) component of the heart rate variability measure of variance in beat-to-beat interval (Camm et al., 1996; Stajzel, 2004). Heart rate or R-wave to R-wave (the largest depolarization peak in an EKG recording of a heart beat, corresponding to contraction of the left and right ventricles) interval information can be translated into the frequency domain via Fast-Fourier transform, and subjected to spectral analysis (Fig. 1). A number of studies have identified a principal influence of sympathetic autonomic nervous system activity on low-frequency power (0.04–0.15 Hz), whereas parasympathetic activity and respiration are linked to higher power in the high-frequency band (0.15–0.50 Hz) (Malik, 2008). Heart rate variability measures demonstrate stable individual response patterns across situations (e.g. stress-tasks), and these individual differences are also stable across time (Berntson & Cacioppo, 2004). In this, they show trait-like characteristics similar to personality traits, and thus could potentially act as their biomarkers (Koelsch, Enge, & Jentschke, 2012).

Factors linking openness to experience and sympathetic HRV are, of course, not conclusive; Indeed, to the best of our knowledge this association has not been tested. Suggestive evidence includes research showing that HRV is linked to differences in attention (Hansen, Johnsen, & Thayer, 2003) and with sympathetic cardiovascular influences inducing more adaptive attentional state (Duschek, Muckenthaler, Werner, & del Paso, 2009). In addition, music is a common elicitor of aesthetic chills, and cardiovascular measures including heart rate and blood pressure vary greatly in response to music, and even music conducting (Harrer & Harrer, 1977) In a further study, HRV was found to be responsive to music: listening to sedative and excitative music increased LF power component and LF/HF ratio, while both measures decreased in the no-music condition, suggesting sympathetic nervous system activation as a response to music stimuli (Iwanaga, Kobayashi, & Kawasaki, 2005).

Based on these earlier research findings, we tested the prediction that higher openness to experience would be associated with increased low-frequency power in the heart rate signal at baseline, reflecting sympathetic activation. Conversely, we predicted that this relationship would not hold for high-frequency power, which reflects activity in the parasympathetic activity. More speculatively, because HR was recorded under both stress and baseline conditions, we also explored whether these relationship would differ depending on whether LF heart rate power was elicited under a non-task baseline condition or a cognitive stressor. Based on research indicating both that creative responding occurs primarily under non-task directed situations (Hennessey & Amabile, 2010), and evidence that under stress, the heart-rate response is primarily driven by emotional responding, we predicted that the link between O and LF heart rate power would be stronger under baseline than under a stress (Pagani et al., 1991). We tested these hypotheses using data from Wave II of the MacArthur Foundation Survey for Midlife Development in the U.S. (MIDUS II: Ryff & Almeida, 2009). All analyses controlled for covariates linked to heart function: age, sex, weight, height, and body mass index (BMI), as is standard in analysis of cardiovascular fitness measures (Aberg et al., 2012).

## 2. Method

### 2.1. Participants

Participants were all eligible persons in Project 4 of Wave II of the MacArthur Foundation Survey for Midlife Development in the U.S. (MIDUS II: Ryff & Almeida, 2009). The Project 4 sub-sample participants were assessed for major biomarkers, including HRV (Love, Seeman, Weinstein, & Ryff, 2010). All 952 subjects for whom biomarker and openness scores were available were included in the analyses (mean age 54.6 years, SD = 11.6). In total, there were 429 males (mean age 55.3 years, SD = 11.9) and 523 females (mean age 54.03 years, SD = 11.3).

### 2.2. Measures

#### 2.2.1. Heart rate variability measures

The electrocardiogram (ECG) was recorded continuously during the protocol. Analog signals were digitalized at 500 Hz and 16-bit resolution with an analog-to-digital board (National Instruments, Austin, TX), and then processed by proprietary event detection software implementing an algorithm for identifying consecutive ventricular depolarizations (or RR intervals) based on the recordings of maximum voltage. These maxima were detected automatically, with post-detection visual inspection of marked-up waveforms to correct any software errors (Berntson, Quigley, Jang, & Boysen, 1990; Dykes et al., 1986). Heart rate variability was computed from this beat-to-beat information. The resulting data were used to calculate cardiovascular reactivity in frequency domain with separate assessments of sympathetic and vagal activity based on power in the low (LF: 0.04–0.15 Hz) and high (HF: 0.15–0.50 Hz) frequency bands, respectively (Bootsma et al., 1994; Camm et al., 1996). These measures have been shown to be reproducible in normal as well as clinical samples (Camm et al., 1996).

Heart rate was assessed in a seated position under two conditions: rest and cognitive stress. Stress was induced twice: once with a math task (Turner, Sims, Carroll, Morgan, & Hewitt, 1987; Turner et al., 1986), and once with an attentional-control stressor (Stroop). In the arithmetic task, subjects perform addition and subtraction tasks that adaptively increased or decreased in difficulty to

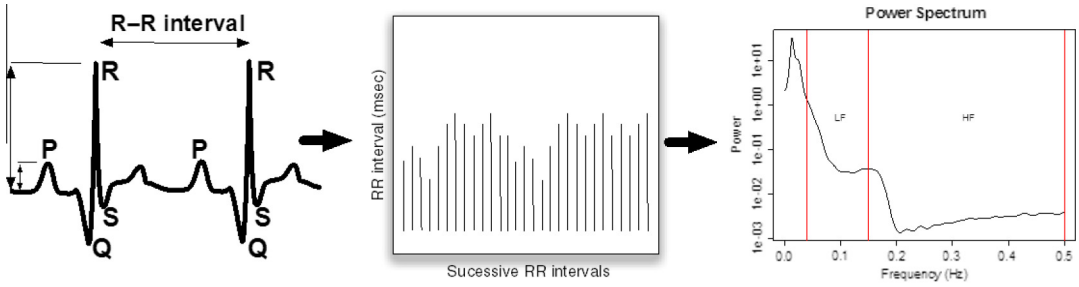


**Fig. 1.** Processing from EKG signal interval RR-intervals and power spectrum. (LF: 0.04–0.15 Hz) and high (HF: 0.15–0.50 Hz).