



## EXTRAVERSION, NEUROTICISM AND BRAIN FUNCTION: A PET STUDY OF PERSONALITY\*

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**Summary**—The personality dimensions Extraversion and Neuroticism seem associated with differences in central nervous system function. We used positron emission tomographic (PET) measures of regional cerebral blood flow (rCBF) to investigate central neural differences in Extraversion and Neuroticism, as determined by the Swedish version of the NEO PI-R personality inventory. A median-split defined extraverts from introverts and relatively more and less neurotic subjects. The relative rCBF in the caudate nucleus and the putamen was higher in introverts than extraverts. In introverts, but not extraverts, activity in the putamen was left-lateralized. These areas have high concentrations of dopamine terminals, implicating a dopaminergic basis for individual differences in Extraversion. As a function of Extraversion rCBF did not differ in the prefrontal, orbitofrontal, temporopolar, cingulate, primary visual cortex, the thalamus and the hypothalamus. Thus, individual differences in Extraversion correlate to subcortical rather than cortical brain regions. No rCBF differences were related to Neuroticism. Because introverted subjects displayed an increased neuronal activity in brain regions previously associated with learning, motor and vigilance control, since those behaviors in part define Introversion, a subcortical neostriatal and possibly dopaminergic, rather than a solely cortical correlate of the personality dimension Extraversion is supported.  
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### INTRODUCTION

Personality is defined as a long-lasting fundamental characteristics of individual behavior. Several theories have linked personality to biology and brain functions (cf. Eysenck, 1967; Gray, 1972; Zuckerman, 1991). The personality theory of Gray (1972) focuses on the two personality dimensions, anxiety and impulsivity, and their relationship to the two functional brain systems: the 'behavioral inhibition system' and the 'behavioral activation system'. Zuckerman's (1991) theory is based on the relationship between the personality trait Sensation Seeking and central monoamines, especially the catecholamines, while Cloninger's theory (see Zuckerman, 1991 for a review) describes the balance between the transmitters dopamine, serotonin and noradrenaline in determining the personality dimensions: Novelty seeking, Harm avoidance, Reward dependence, and Persistence. The influential arousal theory of Eysenck (1967) claims that the personality dimensions; Extraversion–Introversion and Neuroticism–Stability account for most of the variance in the personality domain, and propose an inverse relationship between the degree of Extraversion and cortical arousal, as sustained by a loop connecting the reticular formation with the cortex. Extraverts are considered to be under-aroused, leading to a need to seek external stimulation in order to increase their arousal levels, while introverts are considered to be over-aroused, and tend to avoid stimulation. Neuroticism, on the other hand, is said to relate to an imbalance within the limbic system, and differences are held to emanate largely from constitutional factors such as inherited lability of the autonomic nervous system (ANS), and between excitation and inhibition within the central nervous system

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(CNS) (Eysenck, 1967). Supporting a constitutional factor in individual differences in personality, there is a considerable heritable component of 30–60% for Extraversion and Neuroticism (c.f. Petersen *et al.*, 1988).

Validating the Extraversion–Introversion dimension in terms of indirect behavioral measures of cortical arousal has been a line of research. Increased vigilance among introverts, as compared with extraverts, has almost invariably been reported (for a review see Matthews, 1992), and higher perceptual sensitivity among introverts than extraverts has also often been found (cf. Siddle *et al.*, 1969). In addition, an increased conditionability characterizes introverts better than extraverts, during conditions of normal arousal (cf. Fredrikson & Georgiades, 1991). However, psychophysiological methods have not consistently supported individual differences in autonomic nervous system reactivity related to Neuroticism (Fahrenberg, 1992). The fact that ANS measures of arousal seldom correlate (Gale & Eysenck, 1992) suggests that cortical arousal does not affect peripheral measures in an unidimensional manner. Therefore, direct measurements of brain activity using modern brain imaging techniques provide a better test of the theoretically proposed (cf. Eysenck, 1967) CNS differences in Extraversion and Neuroticism.

Direct measurements of brain function related to individual differences in Extraversion and Neuroticism have been conducted in some studies. Mathew, Weinman, and Barr (1984) determined regional cerebral blood flow (rCBF) using the <sup>133</sup>Xenon inhalation technique in 51 healthy females. Extraversion but not Neuroticism, as determined by the Eysenck Personality Inventory (EPI), was inversely correlated with resting rCBF in all brain regions measured. Using positron emission tomography (PET) and glucose metabolism, Haier *et al.* (1987) investigated 18 patients with generalized anxiety disorder (GAD) and nine normal controls who completed the Eysenck Personality Questionnaire (EPQ), and were scanned during a continuous visual performance task, which also included motor responses. Significant positive correlations between the degree of Extraversion and regional glucose uptake in the putamen, the caudate nucleus, the cingulate gyrus, the hippocampal and the parahippocampal gyrus were reported. Furthermore, significant positive correlations were found between Neuroticism and regional glucose uptake in the pons and inferior temporal areas. However, because Haier *et al.* (1987) mainly studied patients with GAD their data confounds normal variation in personality with anxiety proneness. This hampers conclusions. Stenberg *et al.* (1990) measured rCBF in 37 normal healthy *Ss* during resting conditions using the <sup>133</sup>Xenon inhalation technique, and related Extraversion and Neuroticism as measured by EPI to brain activity. Significantly higher rCBF in introverts, as compared with extraverts, was found bilaterally in the temporal lobes. In the study by Stenberg *et al.* (1990) there were no significant rCBF differences between *Ss* being high and low in Neuroticism. Semple *et al.* (1991) measured glucose uptake using PET, and found a positive correlation between Neuroticism and glucose metabolism in the orbitofrontal cortex in a sample of 27 healthy *Ss*, but not in an additional sample of 44 healthy *Ss*. Ebermeier *et al.* (1994) correlated blood flow during rest to Extraversion and Neuroticism as measured with the EPQ, using single positron emission tomography (SPECT) with <sup>99m</sup>Tc-Exametazime as a tracer that corresponded to blood flow measurements in 51 healthy *Ss*. Positive correlations were found between Extraversion and tracer uptake bilaterally in the anterior and posterior cingulate cortex, while no associations were obtained for Neuroticism.

Generally, the Extraversion personality dimension seems to have a more consistent relationship to central neural activity than Neuroticism. However, the relationship between Extraversion and rCBF is not consistent between studies. Some of the study variation cited above might reflect study design differences. For example, all but one study used the resting state as the study paradigm. This yields increased residual variance in studies of brain function (cf. Andersson, Fischer & Schneider, submitted). To control for this aspect of resting differences, *Ss* in the present study viewed a neutral videotape of park scenes. The moderate intensity of the visual stimuli and the PET investigation itself might yield a differentiation between more and less extraverted *Ss* as suggested by for example Stenberg *et al.* (1990), who argued that intermediate levels of external arousal bring out optimal differences associated with personality. Data from a study by Wik and Wiesel (1991) support the finding that the PET investigation itself results in positive correlations between anxiety and brain glucose metabolism. Thus, the uncertainty experienced during the PET investigation might be sufficient to produce the rCBF differences as a function of Extraversion and Neuroticism. With the object of studying individual differences in central nervous system activity as related to the Extra-

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