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Personality and the neural efficiency theory

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ABSTRACT

The neural efficiency theory was formulated in the field of intelligence research and it posits that better performers require less brain activity to successfully perform a task of a given difficulty level. Here we suggest that in the field of personality research, the neural efficiency concept could be reformulated so that habitual behavior requires less brain activity. To test this hypothesis, 46 participants were presented with a social interactions task, in which they had to choose one out of three ways of interaction with a virtual 'person': 'attack', 'avoid', or 'make friends', while EEG was recorded simultaneously. Personality was assessed using the Eysenck Personality Profiler. Extraverts made more friendly choices and these choices were accompanied by smaller event-related theta synchronization in the left prefrontal cortex. Neuroticism did not show significant behavioral effects, but in high neuroticism scorers, the choice of avoidance was accompanied by smaller theta synchronization in the right prefrontal cortex. Psychoticism was positively associated with the number of aggressive choices and in high psychoticism scorers, these choices were accompanied by smaller theta synchronization in the left precentral cortex. These results are consistent with the extension of the neural efficiency concept for personality.

1. Introduction

Personality and intelligence provide an established and comprehensive frame of reference for the description of an individual (Furnham & Chamorro-Premuzic, 2004). They should be considered orthogonal constructs (see e.g., Eysenck, 1994; Hofstee, 2001; Zeidner & Matthews, 2000) although weak to moderate correlations between intelligence and personality scores have been reported (Ackerman & Heggestad, 1997; DeYoung, Peterson, & Higgins, 2005). Since twin studies show that individual differences in both personality (Borkenau, Riemann, Angleitner, & Spinath, 2001; Plomin, DeFries, McClearn, & Rutter, 1997) and intelligence (Deary et al., 2009) have strong genetic determination, the existence of physiological bases of personality and intelligence seems mandatory (Eysenck, 1994).

Most popular biological theories of personality, such as the Eysenck's theory (Eysenck & Eysenck, 1985) and the Reinforcement Sensitivity Theory by Jeffrey Gray (1987), posit that individual differences in the activity of biological systems underlie the manifestation of personality. These individual differences are partly genetically determined and partly arise in the course of development as a response to environmental demands. Moreover, the gene-by-environment interaction makes a significant contribution to the development of both pathological conditions (Caspi et al., 2003) and temperamental characteristics (Stein, Schork, & Gelernter, 2008).

Here we suggest that personality traits, just as ability traits, also include individual differences in behavioral skills. For example, extraverts may have better ability to understand the meaning and the implications of a social situation, as well as emotional states of other people. Indeed, empirical evidence shows that extraversion correlates positively with emotional intelligence (Petrides, Vernon, Schermer, Ligthart, Boomsma, Veselka, 2010). The choice of a behavior in a particular situation depends on both the value of the expected outcome and the probability of its attainment. While the former depends on the activity of biological systems (Gray, 1987), the latter depends on availability of respective skills. In the course of development, dispositional characteristics precede and actually guide the attainment of respective behavioral skills (Bjørnebekk, 2007), but it also depends on environmental demands. For example, individualistic Western cultures encourage the development of extraverted self-enhancing behaviors, whereas collectivistic Eastern cultures promote self-effacing behaviors as more socially acceptable (Hofstede & McCrae, 2004). Availability of behavioral skills makes the choice of respective behavior more probable and the realization of this behavior strengthens the respective skills, acting as a positive feedback loop.

The idea of behavioral skills allows laying a bridge between personality and intelligence research and paves the way for the application in

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the former domain of the so-called neural efficiency theory (NET), which is very popular in the research of neural correlates of intelligence. The emergence of this concept is to be seen in Haier et al.'s (1988) paper and a comprehensive review of its evolution could be found in Neubauer & Fink (2009). The NET suggests that better performers require less brain activity to successfully perform a task of a given difficulty level (Neubauer & Fink, 2009). Thus, fast-performing adults often show lower activity than slow performers in select task-positive regions (Rypma & D'Esposito, 1999).

Some authors state that this usage of the concept of efficiency is empty and simply redescribes activation differences rather than providing a useful explanation of them (Poldrack, 2014). Indeed, one may argue that the principle of more effort for a subjectively more difficult task is too general. However, a generality of a theory should not be necessarily considered a weakness. Here we argue that, with all due reservations, the NET could in principle be extended to personality research. Since, according to our hypothesis, a higher score on a personality dimension is associated with higher availability of respective skills, one may expect that, in line with the NET, a behavior would require less brain activity if it was characteristic of this individual.

In order to test this hypothesis empirically, we chose the domain of social behavior, because for humans as social beings interactions with other people constitute the most important part of their lives. Eysenck, Wilson, & Jackson (2000) once noted that there are only three major ways of dealing with the challenge presented by other people. The first choice is aggression and hostility, the second is fear and flight, and the third is social interaction. They suggested that these three kinds of interpersonal relations are reflected in personality dimensions of psychoticism, neuroticism, and extraversion, respectively. Somewhat transformed, these ideas have found their implementation in personality dimensions of agreeableness, neuroticism, and extraversion of the most currently popular model of personality — the so-called Big Five (McCrae & Costa, 2003).

This implies that each individual, depending on his or her personality, may be predisposed to choose one major way of dealing with other people. However, many empirical studies have led investigators to the 'depressing' conclusion of a failure of most personality tests to predict what people actually do in particular situations (Mischel, 2009). Some authors (Shweder, 1991) even argued that individual differences in conduct are strictly context dependent and do not generalize across contexts. This 'person-versus-situation debate' persisted for years and resulted in many studies and theories examining in detail the structure and organization of individual differences in social behavior and the expressions of personality (Andersen & Thorpe, 2009; Mischel & Shoda, 1995, 2008; Mischel, Shoda, & Ayduk, 2008; Van Mechelen, 2009). Here we argue that when, due to situational demand, a person chooses behavior that is not typical of him/her, this behavior would be accompanied by heightened emotional arousal and this could be revealed using appropriate measures of brain activity.

In this study, we used virtual social interactions as an experimental model of social behavior (Knyazev, Slobodskoj-Plusnin, Bocharov, & Pylkova, 2013). In this model, the participant is presented with a choice of one out of three variants of social behavior — friendship offering, avoidance, or aggression. Electroencephalogram (EEG) was used as a measure of brain activity. The vast majority of NET studies used alpha desynchronization as a marker of mental effort (Neubauer & Fink, 2009), because alpha oscillations are almost universally accepted as a reverse measure of cortical activity. However, in recent years, the understanding of functional correlates of alpha oscillations has evolved. Klimesch, Sauseng, & Hanslmayr (2007) suggested that alpha synchronization might reflect top-down control processes, whereas alpha desynchronization reflects bottom-up release of this control. These ideas posit a direct and active role for alpha oscillations in the mechanisms of attention and consciousness (Palva & Palva, 2007). Besides, much data show that different characteristics of alpha activity correlate with cognitive processes, whereas motivation and emotion are more associated with low frequency oscillations (see Knyazev, 2007 for review). It seems reasonable to suggest that contrary to intelligence, personality must be more associated with emotional arousal. Therefore, as a marker of emotional arousal we chose event-related synchronization in the theta band. However, to allow for the comparison with other NET studies, which mainly investigated alpha oscillations, we also included in the analysis this frequency band. We predicted that people with high extraversion, neuroticism, and psychoticism scores would more frequently choose friendship, avoidance, and aggression, respectively, and these choices would be accompanied by lower theta synchronization than in low scorers on respective personality dimension.

2. Materials and methods

2.1. Participants

The social interactions data were collected in a sample of 46 participants (24 men; age range 18 to 30 years). The sample consisted of healthy, right-handed volunteers with normal or corrected to normal vision who received a sum equivalent to about 5% of the monthly living wage for participation. All applicable subject protection guidelines and regulations were followed in the conduct of the research in accordance with the Declaration of Helsinki. All participants gave informed consent to the study. The study has been approved by the Institute of Physiology and Basic Medicine ethical committee.

2.2. Instruments and procedures

Participants sat in a soundproof and dimly illuminated room. As stimulation we used an ensemble of the photographs presented by Ekman & Friesen (1976). We selected 30 photographs, specifically, 5 different females and 5 different males with 3 different facial expressions (angry, happy, and neutral). The pictures were presented in black and white (17 × 17 cm) and displayed on a screen at a distance of 120 cm from the participant. Participants were asked to imagine that faces are real persons whom they have to interact with. They had to choose one out of three options: 'attack', 'avoid', or 'make friends'. First, a fixation cross appeared at the center of the screen for 1 s. Then a face picture was presented. Angry, happy, and neutral faces were delivered randomly, and inter-stimulus-interval randomly varied between 4 and 7 s. The number of face stimulations was 150 for each participant, including 50 faces of each category. After the experiment, the participants filled out a set of questionnaires and were debriefed. Personality was assessed using the extraversion, neuroticism, and psychoticism scales from the Eysenck Personality Profiler (Eysenck et al., 2000; Knyazev, Belopolsky, Bodunov, & Wilson, 2004), which was filled out before the experiment by a half of participants and after it by the other half.

2.3. EEG data acquisition

32 EEG electrodes were placed on the subject's scalp. The electrodes were mounted in an elastic cap on the positions of the international 10–20 system, which ensured homogenous scalp coverage. A mid-forehead electrode was the ground. The signals were amplified with a multichannel biosignal amplifier with bandpass 0.05–70 Hz, −6 dB/octave and continuously digitized at 300 Hz. The electrodes were referred to linked-mastoids. The horizontal and vertical EOG was registered simultaneously. EEG data were artifact-corrected using ICA via EEGLAB toolbox (http://www.sccn.ucsd.edu/eeglab/) and recomputed to average reference.

2.4. Channel-level EEG data analysis

To assess choice-related changes in spectral power, event-related spectral perturbations (ERSPs) were calculated. The ERSP (Makeig, 1993) shows mean log event-locked deviations from baseline-mean