Author: R. Buckingham
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Author Address: rbuckingham@csu.edu.au

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Abstract

In the same year that Eysenck (1967) published his biological account of extraversion, Claridge (1967) identified several problems with the theory. In addressing issues raised by Claridge, Robinson (1996) has detailed a promising modification to Eysenck's theory. Drawing on Robinson's theory it was hypothesised that differences in resting electrodermal activity would contrast extraverted-neurotics (low arousal) and introverted-neurotics (high arousal). The EPQ was used to identify four extreme groups of female participants: **extraverted-stable** (n=16), **extraverted-neurotic** (n=15), **introverted-stable** (n=8) and **introverted-neurotic** (n=16). EDA measures of SCL and NS-SCR were collected during two rest periods. Planned contrasts between the **extraverted-neurotic** and **introverted-neurotic** groups provided support for Robinson's theory on SCL but not NS-SCR. It was argued that the results for NS-SCR frequency could be accommodated by Robinson's theory if NS-SCR was conceptualised as a measure of cortical reactivity to unspecified stimuli rather than as a measure of tonic arousal.

Key Words: extraversion, arousal, electrodermal activity.

Extraversion and neuroticism: An investigation of resting electrodermal activity

1. Introduction

Eysenck (1991) suggested that his personality dimensions of neuroticism, extraversion and psychoticism have greatest claim to biological significance as they are based in the first instance on clinical criterion groups. In developing markers for these three dimensions, Eysenck began by comparing neurotics (hysterics and dysthymics) with the general population. Factor analysis was then employed to identify suitable questionnaire items for assessing neuroticism (Eysenck, 1952) and subsequently to maximise the independence of neuroticism, extraversion and psychoticism (Eysenck, 1959; Eysenck and Eysenck, 1964; Eysenck and Eysenck, 1975; Eysenck, Eysenck and Barrett, 1985).

In 1967 Eysenck advanced his biological account of extraversion and neuroticism. Differences in extraversion were causally linked to the ascending reticular arousal system (ARAS), while differences in neuroticism were causally linked to the visceral brain or limbic system. Relative to extraverts, introverts were thought to have high ARAS sensitivity and consequently "are chronically more cortically aroused" (Eysenck and Eysenck, 1985, p. 197). Relative to emotionally stable

individuals, neurotic individuals were thought to have higher visceral brain sensitivity and consequently greater autonomic activation.

This theory generated a large volume of experimental research, which initially focused on the differences between hysterics and dysthymics (Claridge, 1967). These two clinical groups were thought to be equally high on neuroticism but at opposite poles on the extraversion dimension. Hysterics were thought to be neurotic and extraverted, dysthymics neurotic and introverted. When the research focus shifted to the general population the emphasis on extraversion persisted and there have been comparatively few studies of neuroticism.

Eysenck (1994) observed **that** the most direct test of any biologically based theory of personality is to be found at the physiological level. Evidence from physiological studies, however, provides little support for extraversion-related differences in tonic arousal (e.g., De Pascalis, 2004; Eysenck, 1994; Gale and Edwards, 1986; O'Gorman, 1984; Stelmack and Geen, 1992; Zuckerman, 1991). The strongest physiological evidence in favour of Eysenck's extraversion-arousal hypothesis comes from studies employing electrodermal measures. Indices of electrodermal activity (EDA) reflect changes in sweat gland activity, thought to be mediated primarily by sympathetic cholinergic inervation (Fowles, Kochanska and Murray, 2000). Dawson Schell and Filion (2000) identify three neural mechanisms or pathways which may have either excitatory or inhibitory influences on the

sympathetic nervous system. These include influences from the hypothalamus and limbic system, influences from the premotor cortex and the frontal cortex, and influences from the brainstem reticular formation. Electrodermal research focusing on the Eysenckian dimensions has typically operationalised heightened arousal in terms of a high frequency of non-specific skin conductance response (NS-SCR) or high skin conductance level (SCL) (Raskin, 1973; Stelmack and Geen, 1992).

Studies that have looked at the frequency of NS-SCR have produced several positive findings. In line with Eysenck's extraversion-arousal hypothesis, Coles, et al. (1971), Crider and Lunn (1971), Cruz and Larsen (1995), Gange, Geen and Harkins (1979), and Mangan and O'Gorman (1969) all report that introverts exhibit a higher frequency of NS-SCRs than extraverts during baseline or resting conditions. However, interpretation of these findings in relation to Eysenck's theory needs to be tempered by the fact that over 35 published studies have found no extraversion related differences on NS-SCR frequency (Stelmack and Geen, 1992). Furthermore studies looking at SCL during baseline or rest conditions have generally failed to find any differences (e.g., Coles, Gale and Kline, 1971; Davis and Cowles, 1988; Nielsen and Petersen, 1976). Davis (1988) similarly found no difference in mean SCL between extraverts and introverts but did report that SCL tended to exhibit high test-retest reliability for extraverts but not introverts.

Given the general lack of support for the arousal hypothesis, Eysenck (1994) came to advocate that the research focus should shift to the study of extraversion-related differences in arousability or reactivity to stimuli. Consequently there have been few recent investigations of extraversion-related difference in resting electrodermal activity.

1.1. Problems with Eysenck's arousal theory

In the same year that Eysenck published his biological account of personality, Claridge (1967) identified several problems with the theory. A central concern for Claridge was the clinical criterion groups selected by Eysenck to identify basic personality dimensions. Claridge (1967) conducted a series of studies using both psychological and physiological variables, which indicated that hysterics and dysthymics differ on at least two causal continua and not one as proposed by Eysenck.

Claridge (1967) also questioned the orthogonality of extraversion and neuroticism. Despite Eysenck's attempts to maximize the independence of extraversion and neuroticism, factor analytic studies have frequently reported a negative correlation between the two dimensions (Zuckerman, 1991). Eysenck remained uncertain as to whether this negative correlation was attributable to psychometric faults or some underlying relationship between extraversion and neuroticism (Eysenck and Eysenck, 1985).

Claridge (1967) and others (e.g., Blakemore, 1967) also criticised Eysenck's arousal theory for being neurologically too general. There has long been evidence for two relatively distinct portions of the reticular formation (e.g., Jasper, 1949; Lindsley, Bowden and Magoun, 1949; Samuels, 1959): a caudal mesencephalic (i.e., the ARAS) and a diencephalic (i.e., the diffuse thalamic projection system, DTPS). In comparing these two portions of the reticular formation Lindsley (1960) suggested that the ARAS exerts a non-specific and long lasting generalised tonic arousal influence on the cortex. The DTPS on the other hand was thought to have a phasic influence, which controls the distribution and integration of impulses arriving at the cortex.

1.2. Robinson's Thalamocortical Theory of Personality.

Building on Eysenck's work Robinson (1983, 1986) has developed a theory of personality which attempts to address Claridge's concerns. Robinson (1996) has proposed two neurological dimensions which together account for differences on the dimensions of extraversion and neuroticism. The first neurological dimension, the relative effectiveness of thalacomortical excitatory and inhibitory neurons is thought to determine the immediate *reactivity* to stimuli. Robinson's first neurological dimension provides the basis for a personality dimension

of sociability running between the extraverted stable (low reactivity) and the introverted neurotic (high reactivity).

The second neurological dimension identified by Robinson (1996) is *overall arousability*, which he contends is a function of both immediate reactivity and the extent to which activity in thalamocortical circuits can persist after the cessation of stimulus input. Robinson argues that this latter determinant will be a function of variation in the product of thalamocortical excitation and inhibition and variation in a constant associated with the tonic influence of the brain-stem reticular arousal system. Differences in overall cerebral arousability are thought to underlie an impulsivity dimension running between the extraverted neurotic (low arousability) and the introverted neurotic (high arousability).

As a consequence of high arousability the introverted neurotic is thought to have high cerebral arousal. As a consequence of low arousability the extraverted neurotic will have low arousal, but only when external stimulation of the brain-stem reticular arousal system is minimal. Under other circumstances the extraverted neurotic will tend to have high cerebral arousal due to poor inhibitory control over the brain-stem.

At present the status of Robinson's theory rests primarily on its integrated explanation of personality differences and its ability to solve problems identified in earlier schemes. Robinson's theory has the

advantage of accounting for Claridge's observation that hysterics and dysthymics differ on two causal continua, as well as the negative correlation between extraversion and neuroticism. Furthermore, Robinson's theory draws a clear distinction between the personality characteristics associated with the ARAS and the DTPS.

The present study was undertaken with the aim of testing Robinson's theory using EDA measures recorded under relaxed, resting conditions. Both SCL and NS-SCR frequency were used as dependent variables and a quadrant based approach was used to explore differences on extraversion **and** neuroticism. Planned contrasts were used to test the hypotheses that neurotic extraverts would have a lower SCL than neurotic introverts and neurotic extraverts would have a lower frequency of NS-SCRs than neurotic introverts.

2. Methods

2.1. Participants

2.1.1. Participant Selection

Participants were selected from a pool of 877 University of Sydney students who completed the EPQ as partial fulfilment of the research participation option in their introductory psychology course.

As the subject pool available to the present experiment was mainly female and few males reached the criteria for inclusion into any one of the experimental groups only female respondents aged between 17 and 29 years of age were considered for this study (n=688). Eysenck and Eysenck's (1975) adult norms were used to assign respondents to one of four groups defined by scores of at least 1 SD above or below the mean on both E and N scales and a score of 10 or less on the lie scale. To increase the number of respondents eligible for the introverted-stable group, the E and N criteria for inclusion were relaxed to a score of less than 10 on both scales. The use of these four groups enables a comparison of Robinson's model with that of Eysenck's.

Respondents eligible for the experiment were questioned about their medical history and excluded if they reported a recent history of medication, clinical treatment for a psychological problem, or auditory or visual impairment. Eligible respondents were further advised that they would be required to abstain from caffeine, alcohol and nicotine for at least 1 hour prior to arriving for the experiment. Participation in the experiment earned further points in the research participation component of the first year psychology course.

2.1.2. Participant Characteristics

Fifty-six participants were classified into one of four experimental groups. However, the EDA data for one participant in the EN group was lost due to equipment failure, reducing the total sample size to 55. Sample sizes for each group were as follows: Extraverted and Stable (ES; n=16), Extraverted and Neurotic (EN; n=15), Introverted and Stable (IS; n=8) and Introverted and Neurotic (IN; n=16). Retest scores were obtained to improve the reliability of classification. Retest reliability coefficients for E, N, P and L were 0.98, 0.97, 0.92 and 0.86 respectively (n=55). By using each subject's seven-digit student identification number for group assignment, the experimenter was blind to group classification until the end of each subject's experimental session.

2.2. Apparatus and Test Materials

2.2.1. Questionnaires

Participants completed a computerized version of the EPQ **(Eysenck and Eysenck, 1975)** in small testing groups of between 4 and 12 individuals. Participants were asked to work quietly without interacting with others in the room. Retesting on the EPQ was

conducted on computer in the psychophysiology laboratory at the conclusion of the experimental session. The interval between test and retest varied between one week and approximately 2 months.

2.2.2. Electrodermal Recording Apparatus and Electrode Placement

Electrodes and application: **Two 8 mm diameter Ag/AgCl electrodes were used to record skin conductance from the volar surfaces of distal phalanges on the index finger and middle finger of the left hand in accordance with recommendations made by Scerbo, Freedman, Raine, Dawson & Venables (1992).**

Johnson and Johnson K-Y jelly was used as an electrolyte (Edelberg, 1967). Although this electrolyte may not be optimal (see Fowles et al., 1981; Grey & Smith, 1984), its effects are unlikely to largely impact the between-group differences focussed on here. Each electrode site was cleaned with distilled water and double sided adhesive collars were placed on the skin under the electrodes to limit the contact area to 1 cm in diameter. Electrodes were recoated weekly to avoid bias potential.

Electrodermal recording: An Autogenic Systems HT-3 Dermograph Trainer applied a constant 0.5 V across the electrodes. The output from the signal conditioner was digitised (200 Hz) on-line by an 8 channel, 12 bit MacLab/8 (A.D. Instruments) analogue to digital converter with a

resolution < 0.015 μS (Venables & Christie, 1980). This system amplified skin conductance using a front-end subject-isolated DC amplifier (MacLab Bio Amp) with a 50 Hz low-pass filter. The MacLab was connected to a Macintosh Quadra (605) computer and was controlled by Chart 3.3.6 software (A.D. Instruments). Digital data were compressed off-line (10:1) and stored on hard disc for subsequent analysis. Following analysis, data were archived on compact disc.

2.3. Procedure

Each participant was tested individually in a single laboratory session, which included both rest conditions and auditory and visual stimulation. These stimulation conditions were included for the collection of ERP data which is reported elsewhere (Buckingham, 2002). No EDA measures were collected during the stimulation conditions as the stimulus parameters specified for the ERP research precluded the collection of theoretically relevant EDA measures.

In view of the evidence relating to an interaction between extraversion, time of day and arousal indices (e.g., Blake, 1967; Revelle, Humphreys, Simon, and Gilliland, 1980; Wilson, 1990) time of testing was held constant for all subjects. Subjects arrived at the laboratory around 12.30 in the afternoon with the experiment concluding at approximately 3.30 in the afternoon.

Participants were seated comfortably in an unlit recording chamber where the ambient temperature was held between 22 and 24 degrees Celsius as recommended by Boucsein (1992). Subjects were fitted with headphones and required to sit passively with eyes closed for two recording stages of approximately 25 minutes each. There was a 5 minute break between recording stages. During this time the light in the recording chamber was turned on and the door left open so subjects could listen to music from the adjoining control room. These steps were taken to reduce the tendency towards drowsiness reported in earlier pilot work. EDA data was collected during the first 3 minutes of each recording stage. At the end of the second recording stage participants were retested on the EPQ.

2.4. Electrodermal Editing, Data Quantification and Data Analysis

Editing and Quantification: Mean SCL was computed by MacLab software for each of the two 3 minute rest periods. NS-SCR frequency was calculated by counting the number of responses > 0.05 μS **(Venables & Christie, 1980)** within each 3 minute rest period. In cases of overlapping waveforms, the second deviation was counted as a NS-SCR provided it exceeded the threshold criterion (the lowest value between the first and second peaks was taken to be the start of the second wave).

The total number of NS-SCRs in each period was divided by three and scored as frequency per minute.

Analysis: To determine test-retest reliabilities over the two recording stages, separate correlational analyses were performed for SCL and NS-SCR measures on all four groups. Separate ANOVAs were conducted for each dependent variable, in each case between subject factors were extraversion (2 levels) and neuroticism (2 levels) with repeated measures on recording stage (2 levels). The two hypotheses were tested using two planned contrasts testing for overall differences between the EN and IN groups.

3. Results

3.1. EDA Test-Retest Reliability

Correlation coefficients for EDA measures are presented in Table 1. SCL showed high test-retest reliability with the lowest coefficient being 0.89 for both the EN and IS groups and the highest being 0.97 for the ES group. Relative to SCL, test-retest reliability across stages was a little lower for NS-SCR with the lowest coefficient being 0.69 for the ES group and the highest being 0.88 for the IN group.

Insert Table 1 about here

3.2. Analysis of variance

3.2.1. EN-IN Planned Contrast for SCL data

The contrast on SCL indicated a significant overall difference between the EN and IN groups [$F(1,51) = 5.69$, $p = 0.021$]. Figure 1 displays means and standard errors for each of the four groups at each recording stage. In accord with prediction, when recording stages are combined, the IN group had a high SCL (Mean = 10.06 μS, SD = 4.90) and the EN group had a low SCL (Mean = 6.63 μS, SD = 2.69).

Insert Figure 1 about here

Consistent with the literature reviewed earlier, the 3-way ANOVA indicated no significant main effect for extraversion [$F(1,51) =$

2.90, p = 0.094]. Furthermore there was no significant main effect for neuroticism [F(1,51) = 0.19, p = 0.668] and no significant interaction between extraversion and neuroticism [F(1,51) = 1.80, p = 0.185]. The only significant effect on the 3-way ANOVA was a main effect for recording stage [F(1,51) = 27.61, p < 0.001]. From Figure 1 it can be seen that all four personality groups show an increase in SCL from stage 1 to stage 2.

3.2.2. EN-IN Planned Contrast for NS-SCR data

The planned contrast for NS-SCR frequency did not support the hypothesis that the EN group would have a lower frequency of NS-SCR relative to the IS group [F(1,51) = 3.38, p = 0.072]. The means and standard errors for each group at each recording stage are displayed in Figure 2. The frequency of NS-SCR was higher for the IN group (Mean = 2.98, SD = 2.99) than for the EN group (Mean = 1.56, SD = 1.39). This difference, however, was part of a broader difference between extraverts and introverts. Extraverts were found to exhibit a significantly [F(1,51) = 5.33, p = 0.025] lower mean frequency of NS-SCR (Mean = 1.45, SD = 1.61) than introverts (Mean = 2.90, SD = 2.63). The 3-way ANOVA revealed no significant main effect for neuroticism [F(1,51) = 0.14, p = 0.711] and no significant interaction between extraversion and

neuroticism [$F(1,51) < 0.01$, $p = 0.968$]. There were no significant stage related effects [$F(1,51) = 2.91$, $p = 0.094$].

Insert Figure 2 about here

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4. Discussion

The planned contrast on SCL produced a significant overall difference in accord with the hypothesis that extraverted neurotics would have lower SCL than introverted neurotics. The second hypothesis that extraverted neurotics would have a lower frequency of NS-SCRs was not supported. In fact, counter to prediction, the only significant finding on this measure was for extraversion generally, with extraverts having a lower NS-SCR frequency than introverts. The only other significant effect on the ANOVAs for EDA measures was a main effect for recording stage [$F(1,51) = 27.61$, $p < 0.001$] in which SCL demonstrated an increase from stage 1 to stage 2. Higher levels of SCL in the second recording stage are likely to be attributable to the

measures taken to ward off drowsiness during the interval prior to recording stage 2 (i.e., turning the light on and music emanating from the control room).

The results from the present study may explain why few studies have found extraversion related differences in resting SCL. Given that extraversion and neuroticism tend to be negatively correlated, studies which have simply looked at extraversion-introversion differences in isolation will most likely have included more stable extraverts than neurotic extraverts. The SCL data reported here would suggest that, in such cases, one pole of the arousal continuum (i.e., the low aroused neurotic extraverts) is being under-represented. The SCL data then suggests a need for a return to the original research focus between extraverted-neurotics (hysterics) and introverted-neurotics (dysthymics).

The planned contrast on NS-SCR frequency did not provide any support for the hypotheses that extraverted-neurotic individuals would have lower NS-SCR frequency than introverted-neurotic individuals. This finding can only be accommodated within Robinson's theory if one re-conceptualises NS-SCR frequency as an index of reactivity (e.g., Taylor, Carlson, Iacono, Lykken and McGue, 1999) rather than tonic arousal.

This distinction may be inferred from the differing ways in which the two EDA measures are derived. The SCL measure used in the present study is an absolute measure in that it is not taken relative to a baseline. SCL may therefore provide an accurate reflection of the general level of cerebral arousal. NS-SCR, on the other hand, is a relative measure in that the subtraction process used to calculate a NS-SCR excludes baseline differences in general arousal level. NS-SCR might therefore better reflect the reactivity of specific neural pathways. According to this argument then, NS-SCR frequency reflects reactivity differences to unspecified stimuli along an ES-IN dimension.

The assumption that SCL reflects tonic arousal differences and NS-SCR frequency reactivity to unspecified stimuli would also help account for the fact that extraversion differences in resting EDA activity have been more frequently reported for NS-SCR frequency than for SCL (e.g., Stelmack and Geen, 1992). The negative correlation between extraversion and neuroticism would dictate that most studies which simply focused on extraversion-introversion differences will contain a greater proportion of stable extraverts (low reactives) amongst the extraverts. Unlike the SCL measure then, with NS-SCR frequency, the extreme personality group at the extraverted pole is likely to be over-represented.

The same reasoning would also suggest that EDA studies which have examined SCR to external stimulation would be **more** likely to find

extraversion related differences than studies which have investigated resting SCL. This suggestion is supported by several studies which report evidence for phasic extraversion related differences in EDA activity. Enhanced SCR of introverts to auditory stimuli of moderate intensity (75 to 90 dB) has been frequently reported in the literature. Relative to extraverts, introverts tend to have larger initial response amplitudes, slower habituation rates, a greater frequency of responses and greater response recovery following habituation (Crider and Lunn, 1971; Mangan and O'Gorman, 1969; Smith and Wigglesworth, 1978; Stelmack, Plouffe and Falkenberg, 1983).

It is also interesting to note that unlike SCL, NS-SCR frequency did not show universally high test-retest reliabilities for all four personality groups. Test-retest reliability on NS-SCR frequency was highest for the IN group (r = .88) and lowest for the ES group (r = .69). The present results would suggest that relative to the ES group, individuals in the IN group are reacting more frequently and consistently to unspecified stimuli.

As Robinson's theory represents a modification to Eyenck's theory, there is considerable overlap between the two. Distinguishing between the two theories is made even more difficult by the fact that there is some ambiguity in Eysenck's position concerning the exact relationship between neuroticism and arousal. According to Eysenck (1967), ascending and descending pathways between the reticular

formation and the hypothalamus ensure that autonomic activation can also produce cortical arousal. Eysenck (1967) suggested that this autonomic influence may, however, be negligible for the most part. Eysenck's theory, like Robinson's theory, therefore implicates not only extraversion but also neuroticism as a personality correlate of arousal. Despite this overlap, arousal measures recorded under minimal external stimulation provide an important test of the two theories. Irrespective of whether the autonomic influence is conceived of as negligible or otherwise, Eysenck's theory does not allow that extraverted-neurotic individuals will have the lowest arousal of all four personality groups defined by extreme scores on both extraversion and neuroticism.

One factor which may have impacted on EDA measures in this study is the use of K-Y jelly as an electrolyte. Grey and Smith (1984) note that the sodium chloride concentration in K-Y jelly is not isotonic to sweat (i.e., in the order .05 molar). Although Grey and Smith report that K-Y jelly did not differ significantly in its effects from a .05 molar NaCl electrolyte, their comparisons were taken over a much shorter time interval than the one employed in the present study. In order to allow unambiguous comparisons with the literature, the use of K-Y jelly is not recommended in future research.

As Claridge (1967) observed, two major problems face any causal account of extraversion and neuroticism. First, to identify the components of psychophysiological activity, which relate to the tonic influence of the ARAS and the phasic influence of the diffuse thalamocortical system. Second, to identify the personality characteristics determined by these two components. In accord with Robinson's theory, the results for SCL indicate that tonic arousal differences are most pronounced between the EN and IN quadrants of Eysenck's extraversion and neuroticism dimensions. The hypothesis that extraverted neurotics would have a lower frequency of NS-SCRs was not supported. It was argued that the results for NS-SCR frequency could be accommodated within Robinson's theory if this measure is conceptualised as an index of reactivity (to unspecified stimuli) rather than tonic arousal.

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