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Ward, Robert; Sreenivas, Shubha; Read, Judi; Saunders, Kate; Rogers, Robert D.

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The role of serotonin in personality inference: tryptophan depletion impairs the identification of neuroticism in the face

Robert Ward¹, Shubha Sreenivas¹, Judi Read², Kate Saunders²
& Robert D Rogers¹

¹School of Psychology, Bangor University,
Brigantia Building, Penrallt Road, Bangor, LL57 2AS

²Department of Psychiatry, University of Oxford,
Warneford Hospital, Oxford, OX3 7JX

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Correspondent author:

Robert D. Rogers
School of Psychology,,Bangor University
Brigantia Building
Penrallt Road
Bangor, LL57 2AS
E-mail: r.rogers@bangor.ac.uk
Telephone: +44 (1248) 382095

Abstract

Serotonergic mechanisms mediate the expression of personality traits linked to vulnerability to psychological illness such as impulsivity, aggression and anxiety; and modulate the identification of emotional expressions in the face as well as emotional learning about broader classes of appetitive and aversive signals. Faces with neutral expressions signal a variety of socially-relevant information, such that inferences about the big-five personality traits, including Neuroticism, Extraversion, and Agreeableness, can be accurately made on the basis of emotionally neutral facial photographs. Given the close link between Neuroticism and psychological distress, anxiety and depression, we investigated the effects of diminished central serotonin activity (achieved by tryptophan depletion) upon the accuracy of 52 healthy (non-clinical) adults' discriminations of personality from facial characteristics. All participants were able to discriminate reliably four of the big-five traits, including Neuroticism. However, the tryptophan-depleted participants were specifically less accurate in discriminating Neuroticism than the matched non-depleted participants. These data suggest that central serotonin activity modulates the identification of, not only negative facial emotional expression, but a broader class of signals about personality characteristics linked to psychological distress.

Keywords: serotonin; personality; Neuroticism; psychological distress

Introduction

Serotonin mechanisms mediate the expression of personality traits linked to mental illnesses, including impulsivity, aggression and Neuroticism (Takano et al, 2007).

High levels of Neuroticism have been associated with increased 5-HTT binding within the thalamus (Takano et al, 2007), while a number of characteristic emotional experiences associated with Neuroticism, such as anxiety, depression, hopelessness, somatization, guilt, hostility, and affective temperament – have been linked to the 5-HTTLPR polymorphism of the serotonin transporter gene (Gonda et al, 2009).

However, to date, there have been no investigations of the role of serotonin activity in the identification of Neuroticism and other aspects of personality in other people.

Other evidence attests to the role of serotonergic mechanisms in the recognition of facial expressions of emotion including, but not limited to, fearful states (Harmer, Rogers, Tunbridge & Goodwin, 2003). Tryptophan depletion – producing temporary reductions in central serotonin activity (Moore, Landolt, Seifritz, Clark, Bhatti, Kelsoe, Rapaport, & Gillin, 2000) – impairs the accuracy of fear recognition in healthy females, and slows latencies for the recognition of fearful expressions in both healthy (non-clinical) male and female adults (Harmer et al, 2003). By contrast, single doses of the selective serotonin reuptake inhibitor (SSRI), citalopram, improve fear recognition in healthy adults (Browning et al, 2007) and normalizes recognition of fearful (and positive) facial expressions in previously depressed individuals (Bhagwagar et al, 2004). These effects are likely to be mediated by altered signaling within neural circuitry encompassing the amygdala (Harmer, Shelly, Cowen, & Goodwin, 2004), suggesting that anti-depressant modulation of monoaminergic activity within limbic circuits alters sensitivity to facial emotional signals (as well as

broader cognitive biases) to support their delayed therapeutic effects (Anderson, Juhasz, Thomas, Downey, McKie, Deakin, & Elliott, 2011; Booij & Van der Does, 2011; Hayward, Goodwin, Cowen & Harmer, 2005; Harmer, Mackay, Reid, Cowen, & Goodwin, 2006; Walsh & Harmer, 2015). However, beyond emotional expressions, the face transmits a variety of other informative cues to social traits. In this study, we examined whether serotonergic modulation influences the accuracy of personality inferences, as cued by neutral facial expressions.

Research on trait inferences shows that observers can identify personality and other important social traits, with modest levels of accuracy, using only impoverished cues. For example, Borkenau and Liebler (1992) established that, even at 'zero-acquaintance', observers could draw accurate personality inferences from short video clips of an individual walking into a room, or quietly facing the camera. Such nonverbal 'thin slices' of behaviour can be famously diagnostic of consensual longer-term impressions; for example, teachers' end-of-semester ratings can be predicted from judges' reactions to a few seconds of silent video clips of those teachers (Ambady & Rosenthal, 1992; 1993). While accurate trait inferences can be drawn on the basis of very short exposures (Borkenau et al, 2009; Rule et al, 2009), accuracy is also affected by the quantity and quality of cues available (Funder & Colvin, 1988; Carney, Colvin, Hall, 2007). In particular, the availability of other cues under individuals' control – such as their hairstyles, clothing, cosmetics, and facial expressions – can improve accuracy of trait judgements (Nauman et al, 2009).

However, even when controllable cues are minimal, facial appearance under constrained and standardised conditions (such as in a passport photograph) can drive accurate trait inferences. Emotionally neutral facial appearances, without evident clothing, cosmetics, or hairstyle cues, can allow accurate judgements of socially-relevant traits as diverse as trustworthiness (Stirrat & Perrett, 2010), women's reproductive success (Pflüger et al, 2012) and even clinically-diagnosed borderline personality disorder (Daros, Ruocco, & Rule, 2016). The accuracy of trait inferences based upon neutral faces suggests an important, but under-explored, channel of social communication in which individuals continuously and involuntarily broadcast cues about behavioural predispositions to observers and potential social partners.

Of primary interest for the present study are findings that factor-analytic personality traits, and in particular trait Neuroticism, can be identified from composite images of neutral facial appearance (e.g., Little & Perrett, 2007; Kramer & Ward, 2010; Jones, Kramer, & Ward, 2012). Neuroticism is marked by a tendency towards fearful emotions, including anxiety, depression, fear, and worry (Vinberg, Miskowiak, & Kessing, 2014; McWilliams, 2003). Neurotic traits are also related to the frequency and intensity of negative emotions (Verduyn & Brans, 2012). Of all the big five personality traits, Neuroticism would be the most closely related to fear (Nettle, 2006). Given that serotonin plays an important role in the recognition of emotional expressions and, in particular, fearful states (e.g., Harmer et al, 2003), we hypothesised that serotonin activity plays a role in identifying trait Neuroticism from the face. We therefore investigated, for the first time, the role of serotonergic activity in making accurate personality discriminations from facial appearance cues. We

tested the specific prediction that tryptophan depletion impairs accurate identification of Neuroticism from neutral facial expressions in healthy adult volunteers.

Method

The experiment was approved by a National Health Service (England) Research Ethics Committee. All participants provided informed consent.

Participants

Fifty-three males and females were recruited from the student population of Oxford University and local community. One female was excluded on the basis of 0% accuracy in discriminating Neuroticism (3.7 SDs from her group mean). No other participant had 0% accuracy. Participants were assessed by an experienced psychiatrist against explicit exclusion criteria using the Structured Clinical Interview for DSM-IV-TR Axis I Disorders (First, Spitzer, Gibbon, & Williams, 2002).

Exclusion criteria included (i) the presence or history of serious physical illness; (ii) history of neurological disorder or head injury; (iii) current, previous or family history of mood-related illness (unipolar or bipolar disorder); (iv) current or previous substance misuse or dependence; (v) other significant psychiatric illness; (vi) any illness or indicators that preclude blood-sampling; (vii) pregnancy or breast-feeding.

Design

The study consisted of a between-subjects, double-blind design. Twenty-five participants (10 men, 15 women) were randomly selected to consume an amino-acid

drink without l-tryptophan (T- treatment), and 27 participants (16 men, 11 women) were to consume an amino-acid drink with l-tryptophan (T+ treatment).

Materials

Amino acids. Amino acids were supplied by Nutricia or Cambridge Bioscience. Amounts for males and females, respectively, were:- l-alanine (5.5g;4.58g), l-arginine (4.9g;4.08g), l-cystine (2.7g;2.25g), glycine (3.2g;2.67g), l-isoleucine (8.0g;6.67g), l-leucine (13.5g; 11.25g), l-lysine monohydrochloride (11.0g; 9.17g), l-methionine (3.0g; 2.5g), histidine (3.2g;2.67g); l-phenylalanine (5.7g;4.75g), l-proline (12.2 g;10.17 g),l-serine (6.9g;5.75g),l-threonine (6.5g;5.42g),l-tyrosine (6.9g;5.75g), l-valine (8.9 g;7.42 g). The T + drink contained l-tryptophan (2.3g;1.92g). Tastes were masked with 5g (15cals; 1.3g carb.) of citric (or malic) acid (cherry-and-vanilla or grapefruit) and artificial sweetener.

Psychometric Assessments. Following the screening interview, participants completed the (i) trait and state Positive and Negative Affect Scales (Watson, Clark & Tellegen, 1988); (ii) Beck's Depression Inventory (BDI-II) (Beck, Steer & Brown, 1996) and (iii) Buss-Perry Aggression Questionnaire (Buss & Perry, 1992). The PANAS consists of two subscales of 20 items, rated using a 5-point Likert scale, to measure positive and negative aspects of emotional experience. Cronbach's α coefficients for the state (i.e. momentary) version of the positive affect and negative affect subscales have been reported as .90 and .87, respectively (Watson et al, 1988). The BDI-II consists of 21 statements that capture the frequency of depressive symptoms over the previous 14 days, with total scores tested against cut-offs to indicate minimal to severe depression (Beck et al, 1996). It has strong convergent

and criterion reliability. A Cronbach's α coefficient of 0.94 indicates high internal consistency (Arnau, Meagher, Norris & Bramson, 2001). Finally, our participants completed the Standard Progressive Raven's Standard Progressive Matrices to assess non-verbal cognitive ability (Raven, Raven & Court, 2004).

Personality Trait Discrimination Task

The trait discrimination task used composites of female faces, reflecting the correlated facial appearance of women who share similar levels of personality traits (e.g., Kramer & Ward, 2010; Jones et al, 2012). We used the full-face stimulus set created by Kramer and Ward (2010), which was made by averaging neutral face photos from women scoring highest and lowest on self-report measures of each big five personality traits (Agreeableness, Openness, Conscientiousness, Extraversion and Neuroticism), as measured on the Mini International Personality Item Pool (Mini-IPIP, Donnellan, Oswald, Baird, & Lucas, 2008). Thus, the composite face pairs reflected regularities in facial appearance which are correlated with specific personality traits. In addition, the stimuli set included two composites which were not based upon the Big Five traits: physical health (used by Kramer & Ward, 2010); and a single presentation based upon depressive symptoms (as described by Scott et al, 2013). These composites were presented once in each stimulus set, providing insufficiently reliable patterns of discriminations; they are not discussed further.

On each presentation (hereafter, trial), one high and one low composite for a personality trait were presented, randomly positioned on either side of centre on a standard computer display, along with a discrimination statement relevant to that trait (e.g., 'More prone to mood swings' for trait Neuroticism, see Figure 1). Participants

made an unspeeded mouse-click on the face best matching the discrimination statement. Each trait was presented four times, using four different discrimination statements (items) adapted directly from the Mini-IPIP (Donnellan et al, 2008).

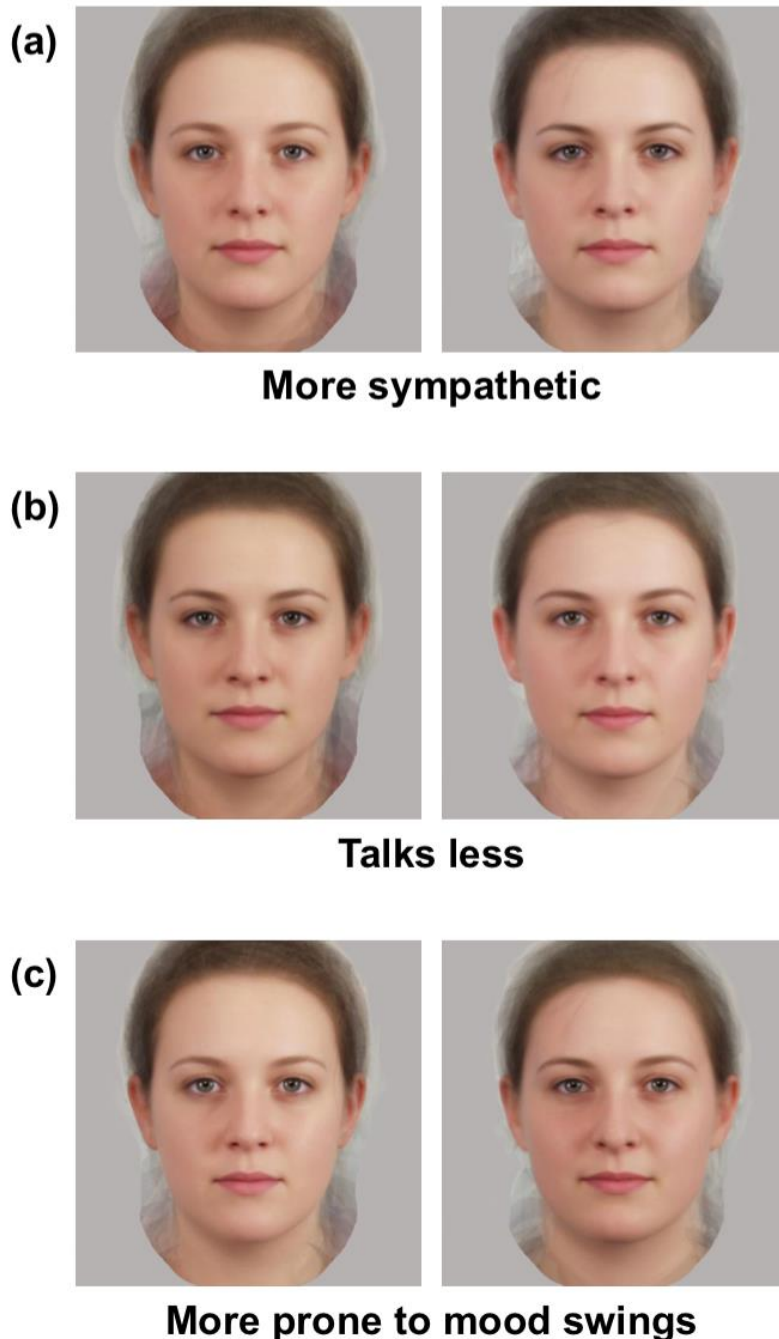


Figure 1. Face stimuli and example discrimination statements for (a) Agreeableness; (b) Extraversion; and (c) Neuroticism. In each case, the face on the left is a composite of 15 women scoring highest on the trait measure, and the face on the right a composite of 15 women scoring lowest on that measure (see Kramer & Ward, 2010 for details). Participants were asked to identify which of the two faces best matched the accompanying discrimination statement.

Procedure

All participants followed a low-protein diet for 24hr before ingesting an amino-acid drink on the morning of the experiment. On arrival at the laboratory, participants completed baseline ratings of state positive and negative affect using the PANAS (Watson et al, 1988). Blood samples (6 ml) were taken for baseline measurements of plasma tryptophan levels and tryptophan/LNAA ratios. Participants then ingested their allocated amino acid drinks. Five hours later (+5hr), participants provided follow-up ratings of state affect with the PANAS, as well as a second blood sample. Participants then completed cognitive assessments and social exchange games that included the computerized trait discrimination task reported here.

Data Analysis

Differences in the number of males and female participants in the T- and the T+ groups were tested with χ^2 tests. Group-matching of age, cognitive ability (scored with the Raven's Standard Progressive Matrices; Raven et al, 2004), trait affect (scored with the Positive and Negative Affect Scale; Watson et al, 1988); and recent depressive symptoms (scored with the Beck Depression Inventory II; Beck et al, 1996) were tested with two-sample t-tests. Changes in total plasma tryptophan, the ratio of plasma tryptophan to other large neutral amino acids (LNAAs), and state positive and negative affect (as measured by the PANAS) were assessed by separate repeated measures ANOVAs with the single between-subject factor of treatment (T- vs T+) and the within-subject factor of time (baseline vs +5 hr).

Using the same full-face stimuli as here, Kramer & Ward (2010) demonstrated that healthy young adults (comparable to our participants) are able to discriminate

reliably Neuroticism, Extraversion and Agreeableness but not Openness or Conscientiousness. Similar accuracy levels of trait discrimination are reported by Kramer & Ward (2011) using hemi-face versions of these stimuli (that is, presenting just the left or right half of the stimuli). Therefore, we focused our analyses upon the most robustly discriminated traits of Neuroticism, Extraversion, and Agreeableness. First, we used 1-sample t-tests to assess all participants' discrimination accuracy against chance (0.5) and 2-sample t-tests to test the prediction that T- participants were less accurate in discriminating Neuroticism and, perhaps, other traits compared to T+ participants. Fifty-two participants provide a statistical power of approximately 0.8 at $\alpha = .05$ (one-sided) to detect medium effect sizes (0.5) in the 1-sample t-tests and medium-to-large effect sizes (0.7) in the 2-sample tests.

As per standard practice (Rogers, Tunbridge, Bhagwagar, Drevets, Sahakian, & Carter, 2003; Bilderbeck, Brown, Read, Woolrich, Cowen, Behrens, & Rogers, 2014), the T- and T+ participants were carefully matched for demographic and psychometric variables: sex; age; depressive symptomology (BDI-II; Beck et al, 1996); trait affect (PANAS; Watson et al, 1988), aggression (Buss & Perry, 1992); and cognitive ability (Raven's Standard Progressive Matrices; Raven et al, 2004).

Since this is the first study of the effects of tryptophan depletion upon the discrimination of personality traits from the face, we also used a mixed-effects binomial model (Bates, 2010) to test effects of these variables upon discrimination on the individual trials, and examine whether their inclusion in the model moderated the reliability of the treatment effects. The model included random intercept terms for participant and for item, and a random slope for treatment by item; and fixed

effects for the remaining predictors, comprising tryptophan depletion, and the demographic and psychometric variables above. All non-categorical predictors (i.e., other than sex and treatment) were zero-centered and scaled to variance of 1.

Results

The demographic and psychometric characteristics of the T- and T+ participants are shown in Table 1. The groups were closely matched for age, cognitive ability (as measured by the Raven's Progressive Matrices (Raven et al, 2004)), recent depressive symptoms (as measured by the BDI (Beck et al, 1996)), trait positive and negative affect (as measured with the trait version of the PANAS (Watson et al, 1988)) and trait aggression (Buss & Perry, 1992), all $t(50) < 2.0$.

	T- participants	T+ participants
Sex (Male: Female)	10:15	16:11
Age	25.2 (1.21)	24.1 (1.20)
Depressive symptoms (BDI)	0.68 (0.34)	1.30 (0.30)
Trait +ve affect (PANAS)	37.5 (1.38)	35.9 (1.15)
Trait -ve affect (PANAS)	11.4 (0.39)	12.9 (0.83)
Total Aggression (Buss-Perry)	44.4 (2.16)	50.3 (2.18)
Raven's Matrices	53.4 (0.69)	54.4 (0.76)
Plasma trypt. ($\mu\text{g/ml}$) 0hr	10.2 (0.39)	10.4 (0.38)
Plasma trypt. ($\mu\text{g/ml}$) +5hr	4.0 (0.68)	21.2 (1.11)
Tryptophan LNAA ratio 0hr	0.14 (0.01)	0.14 (0.01)
Tryptophan LNAA ratio +5hr	0.03 (0.01)	0.16 (0.01)
State +ve affect (PANAS) +0 hr	28.2 (1.66)	29.0 (1.41)
State +ve affect (PANAS) +5hr	27.2 (1.58)	29.0 (1.59)
State -ve affect (PANAS) +0 hr	12.2 (0.57)	12.6 (0.45)
State -ve affect (PANAS) +5 hr	11.5 (0.58)	11.1 (0.27)

Table 1. Demographic and psychometric characteristics, plus tryptophan measurements, of 25 healthy adults who completed a tryptophan depletion protocol and consumed an amino acid drink without tryptophan (T- participants) and 27 healthy adults who consumed an amino acid drink that did contain tryptophan (T+ participants). Beck's Depression Inventory (BDI-II; Beck et al, 1996); trait and state Positive and Negative Affect Schedule (PANAS; Watson et al, 1988); Raven's Matrices (Raven et al, 2004); and Aggression Questionnaire (Buss & Perry, 1992).

As expected (Moore et al, 2000), plasma total tryptophan concentrations showed significant divergence between baseline and +5hr in the T- and T+ participants (see Table 1), $F(1,45)=170.1$, $p<.00001$. Specifically, total tryptophan decreased in the T- participants from 10.2 ug/ml to 4.0 ug/ml, $t(22)=7.20$, $p<.00001$, but increased in the T+ participants from 10.4 to 21.2 ug/ml, $t(23)=11.09$, $p<.00001$. (Note: 3 T+ and 2 T- participants were excluded from these tests because of missing blood samples in the morning or afternoon). The ratio of plasma tryptophan to other large neutral amino acids (LNAAs) also showed different changes following the T- and T+ drinks (see Table 1), $F(1, 45)=69.6$, $p<.00001$. Here, however, only the tryptophan/LNAA ratios following the T- treatment were reduced from .14 to .03, $t(22)=10.4$, $p<.00001$; but the change from .14 to .16 following the T+ treatment was not significant, $t(23)=1.28$, $p=.215$. At +5hr, both plasma tryptophan and the tryptophan/LNAA ratios were reduced in the T- participants compared to the T+ participants, $t(45)=12.4$, $p<.00001$, and $t(45)=11.0$, $p<.00001$, respectively.

Overall, participants' state negative affect (as scored by the PANAS; Watson et al, 1988) showed a significant decline between baseline and +5hr (see Table 1), $F(1, 50)= 12.0$, $p<.002$. State positive affect was unchanged, $F(1, 50)< 1$. Tryptophan depletion did not produce any marked differential changes in either participants' state positive or state negative affect (see Table 1); all $F_s(1, 50)< 1.6$, all $p_s> 0.2$.

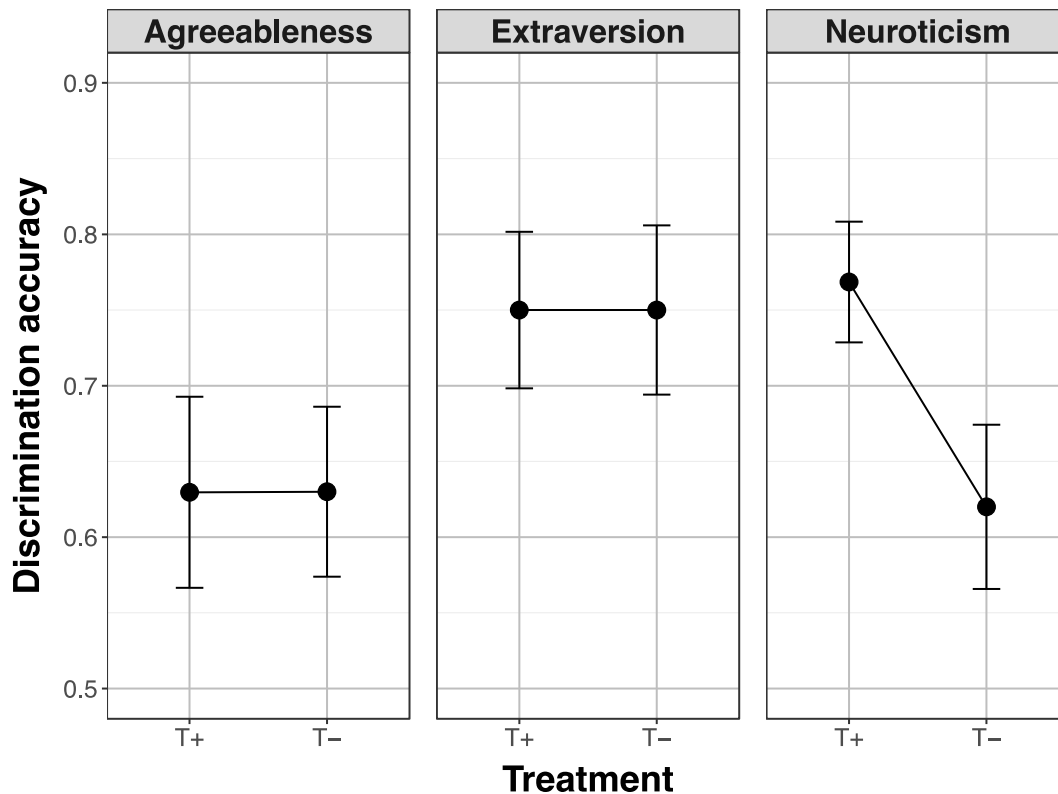


Figure 2. Mean proportionate accuracy on the two-alternative forced-choice trait discrimination of Agreeableness, Extraversion, and Neuroticism in 27 healthy participants who consumed an amino acid drink that did contain tryptophan (T+ participants), and 25 healthy adult participants who had consumed an amino acid drink without tryptophan (T- participants). Error bars represent 1 standard error.

Trait accuracy: Overall, and consistent with Kramer & Ward (2010), participants discriminated Neuroticism with significantly greater accuracy than chance by a 1-sample t-test, $M=.70$, $SE=.035$, $t(51)=5.7$, $p<.0001$, $d = .79$. This was also true of Extraversion, $M=.75$, $SE=.038$, $t(51)=6.65$, $p<.0001$, $d=.92$, and Agreeableness, $M=.63$, $SE=.042$, $t(51)=3.09$, $p=.003$, $d=.43$. Like Kramer & Ward (2010), our participants were not able to discriminate Openness reliably, $M=.50$, $SE=.037$, $t(51)=.13$, $p=.9$, $d=.02$, but unlike Kramer and Ward (2010), they were able to discriminate Conscientiousness, $M=.60$, $SE= .036$, $t(51)=2.8$, $p=.008$, $d=.38$.

Separate comparisons showed that the T- participants showed significantly poorer discrimination of Neuroticism compared to the T+ participants by a 2-sample t-test (see Figure 2), $t(50)=2.23$, $p=.030$, $d=.62$. By contrast, the discrimination accuracies of the T- participants showed no significant changes compared to the T+ participants for both Extraversion and Agreeableness (see Figure 2) or indeed Openness and Conscientiousness (see Table 2), all $t(50)<1$, $p>.3$, $d<.26$).

	T- participants	T+ participants
Agreeableness	0.63 (0.056)	0.63 (0.063)
Extraversion	0.75 (0.056)	0.75 (0.052)
Neuroticism	0.62 (0.054)	0.77 (0.040)
Conscientiousness	0.57 (0.059)	0.63 (0.045)
Openness	0.47 (0.056)	0.54 (0.048)

Table 2. Mean discrimination accuracy (together with their standard errors) for Openness and Conscientiousness in 25 healthy adults who had completed a tryptophan depletion protocol and consumed an amino acid drink without tryptophan (T- participants) and 27 matched healthy adults who had consumed an amino acid drink that did contain tryptophan (T+ participants).

Discrimination accuracy for Neuroticism was examined in detail by analysis with a binomial mixed-effects model (Bates, 2010) (see Table 3). Female participants showed lower accuracy than male participants, $\beta = -0.796$, $SE = 0.360$, $p = 0.027$; and the T- participants showed significantly lower accuracy in identifying neurotic faces, $\beta = -0.934$, $SE = .358$, $p = 0.0091$). No significant effect was found for other predictors (all $\beta_s < 0.33$). The effect of treatment was numerically larger for women than men (T+: women = .75, $SE = .058$; men = .78, $SE = .055$; T-: women = .55, $SE = .065$, men = .725, $SE = .087$). However, an additional treatment*sex interaction term was not significant, $\beta = 0.332$, $SE = 0.699$, and did not improve the model, $\chi^2(1) = 0.21$.

(Intercept)	1.00 (.375)
Sex (male = 0; female =1)	-.796 (.360) *
Age	.131 (.190)
Buss-Perry Total	-.327 (.210)
BDI	.061 (.193)
Trait PANAS +ve	-.047 (.166)
Trait PANAS -ve	-.267 (.189)
Ravens	.004 (.178)
Treatment (T+ = 0; T- = 1)	-.934 (.358) **

Table 3. Mixed-effects binomial modelling of discrimination on Neuroticism trials. Standardised weighting (standard error) for non-categorical factors.

Discussion

To our knowledge, this is the first demonstration that serotonin activity supports the perceptual discrimination of personality. These findings show that tryptophan depletion -- producing temporary reductions in central serotonin activity (Moore et al, 2000; Bilderbeck et al, 2014) -- diminishes the capacity of healthy adults to discriminate Neuroticism, but not other traits, in other people on the basis of facial cues. The T- and the T+ participants were closely matched in terms of sex, age and cognitive ability. Consistent with previous studies involving healthy adult volunteers with no personal or family history of depression (Rogers et al, 2003; Bilderbeck et al, 2014; Wood et al, 2006), there were no marked differences between our T- participants and T+ participants in terms of their state positive or negative affect, either before or following consumption of the amino acid drinks.

Our findings expand our understanding of serotonergic mechanisms in processing of emotional and social signals in other people. Substantial evidence attests to the monoaminergic modulation of emotional recognition in the face (Walsh & Harmer, 2015) and the processing of other appetitive and aversive signals (Boureau et al,

2011; Crockett et al, 2012; Hindi Attar, Finckh & Buchel, 2012). Neuroticism is strongly associated with fearfulness and vulnerability to anxiety, depression and negative rumination (Fergusson, Horwood, & Lawton, 1989; Nettle, 2006; Vinberg, Miskowiak, & Kessing, 2014; Verduyn & Brans, 2012). Thus, our finding that tryptophan depletion impairs the accuracy of Neuroticism discrimination suggests that serotonergic activity mediates the ability to discriminate subtle cues that signal vulnerability to psychological distress in the absence of expressed negative emotion.

Serotonergic mechanisms influence the expression of social behaviours in both humans (Knutson et al, 1998; Moskowitz et al, 2001; Tse & Bond, 2002; Young & Leyton, 2002) and non-human primates (Raleigh et al, 1981; Raleigh et al, 1985) and, in particular, a wide variety of social exchanges with partners and group members (Colzato et al, 2013; Higley et al, 1996; Crockett et al, 2012; Crockett et al, 2008; Wood et al, 2006; Bilderbeck et al, 2014). Twelve days administration of tryptophan in healthy (non-clinical) adults decreases (perceived) quarrelsomeness and increases dominance (Moskowitz et al, 2001; 2003). The present findings suggest that serotonergic influences over social behaviours also incorporate the moderation of sensitivity to the facial signals of vulnerability to distress in (potential or actual) social partners. Important social behaviours — for example, the selection of mates and the pursuit of affiliative relationships — are influenced by the perception and then the appraisal of facial appearances (e.g. Rhodes, 2006). The present data indicate that serotonergic activity mediates these behaviours by its contribution to perceptual sensitivity to cues of psychological vulnerability.

These results also raise the possibility that psychological disorders, such as depression, whose pathophysiology includes serotonergic dysfunction (Bhagwagar & Cowen, 2008; Bhagwagar & Cowen, 2008; Cowen, 2008) are associated with mistaken inferences about other peoples' personalities, especially around vulnerability to psychological distress and illness. Accurate discrimination of mental health can be accompanied by other negative and potentially incorrect inference. For example, Scott et al (2013) and Daros et al (2016, Study 2A) report high levels of accuracy in judging depressive symptoms from facial expressions but, importantly, the faces of individuals with poor mental health were mistakenly judged as lower in warmth and friendliness (Scott et al, 2013), and more negatively in their emotional expressions (Daros et al, 2016). To the extent that depressive symptoms are mediated by serotonergic dysfunction (Bhagwagar & Cowen, 2008; Cowen, 2008), there may be a cycle of psycho-pathogenic effects: (1) healthy observers mistakenly appraise depressive individuals with negative characteristics (Coyne, 1976); and (2) serotonin dysfunction in depression triggers misidentification of personality of others. Together these misperceptions may disrupt social relationships in depressed people.

Tryptophan depletion had no marked effects upon the discrimination of other big-five traits shown to our participants (Agreeableness, Extraversion and Openness or Conscientiousness), suggesting that serotonin activity plays a particular role in the discrimination of Neuroticism. The specificity of the effects of tryptophan depletion reported here also help to rule out a single mechanism for personality discrimination such as, for example, the selection of the more attractive of the two composites presented as the more desirable characteristic (i.e., highly Agreeable, Extraverted, and Stable). Rather, our data suggest that, like the discrimination of emotional

expressions (e.g. Calder & Young, 2005), trait inference based upon facial characteristics depends upon mechanisms that are dissociable across traits. Future investigation will need to delineate the extent to which discrimination of personality from the face share cognitive and neurochemical substrates with the discrimination of emotional expressions (c.f. serotonin and noradrenaline; Harmer et al, 2004).

The present study used the same stimuli and, broadly, replicates the findings of Kramer and Ward (2010) and, in particular, the accurate discrimination of full-face composites for the traits Agreeableness, Extraversion, and Neuroticism. In contrast, to Kramer and Ward, our participants had completed a protocol that included dietary (protein) restriction, a full day of testing, and consumption of amino acid drinks. Collectively, these two datasets, therefore, suggest some robustness in the accuracy of individuals' discrimination of these stimuli. However, in contrast to Kramer and Ward (2010), our participants showed significantly better than chance discrimination of Conscientiousness. Therefore, at present, we cannot be certain about the consistency of Conscientiousness identification across study protocols or participant populations, and are reluctant to draw strong conclusions about the absence of changes in Conscientiousness discrimination following tryptophan depletion.

In these data, women were significantly less accurate than men in the discrimination of Neuroticism. This is unusual, as women are often found to be more sensitive than men in trait inference tasks, and are rarely found to be worse (e.g., Hall & Mast, 2008). This unusual outcome probably reflects the differential effects of the tryptophan depletion across sexes. Tryptophan depletions' cognitive and emotional effects are often greater for women than for men (Booij et al, 2005), including effects

upon the recognition of fearful expressions (Harmer et al, 2003). Sex differences involving tryptophan depletion may reflect differences in hormonal activity or the distribution of receptors (Fehr et al, 2000; Zhang et al, 1999). Here, although not statistically significant, impaired discrimination of Neuroticism following tryptophan depletion was numerically more marked in the women than men. Therefore, the significant main effect of sex upon Neuroticism discrimination accuracy may reflect only the greater impact of depletion upon women's accuracy for neuroticism.

Finally, changes in the recognition of facial expressions of emotion following single treatments of serotonergic or noradrenergic anti-depressants (Bhagwagar et al, 2004; Browning et al, 2007) appear to form part of a complex of cognitive adjustments that presage the therapeutic effects upon mood following continued treatment in clinical populations (Walsh & Harmer, 2015). Further experimentation with tryptophan loading protocols (Murphy et al, 2006; 2009), single or sub-chronic treatments with anti-depressants could indicate whether the accuracy of Neuroticism inferences from the face can be improved by *enhancing* serotonergic activity and other personality inferences in treated and untreated depressed patients. Similarly, trait inferences about potential social partners may regulate approach and withdrawal behaviours, highlighting the issue of how serotonergic modulation of these judgements relates to the activity of the inter-dependent peptide systems implicated in both mood and social bonding, such as oxytocin (Dolen, 2015; Flight et al, 2013).

Notwithstanding these future possibilities, these data provide preliminary evidence that transient reductions in serotonin activity, produced by tryptophan depletion, impair the discrimination between high versus low Neuroticism on the basis of facial

cues. These findings suggest that serotonin activity modulates the detection of physical signals of vulnerability to depression and psychological distress.

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