The sensitive, open creator

David Bridges*#[1,2], Haline E. Schendan*[1]

*= joint primary authors

corresponding author

[1]Cognition Institute, School of Psychology, University of Plymouth, Plymouth, UK

[2]School of Psychology, University of Nottingham, Nottingham, UK

Author 1: David Bridges, School of Psychology (Faculty of Health & Human Sciences), Plymouth University, Cognovo, 3rd Floor Link building, Drake Circus, Plymouth, Devon, PL4 8AA, Tel: 07738283216. E-mail: david.bridges@plymouth.ac.uk.

School of Psychology, University of Nottingham, Nottingham, UK, NG7 2RD. E-mail: david.bridges@nottingham.ac.uk

Author 2: Haline E. Schendan, School of Psychology (Faculty of Health & Human Sciences), Plymouth University, Room A208, Portland Square, Drake Circus, Plymouth, Devon, PL4 8AA. Tel: +44 1752 584804. E-mail: haline.schendan@plymouth.ac.uk.

Manuscript accepted on 14 September 2018 for publication in: *Personality and Individual Differences*

Article Type: SI: Creativity

Section/Category: Research Paper (<5,000 words)

Keywords: creativity; temperament; personality; plasticity; adult personality development

Abstract

Identifying a creative personality has been challenging. Sensitivity was implicated in creativity in early studies but more recently defined as a biologically-based personality dimension (i.e., temperament). In this paper we aim to establish relationships between temperament, personality and creative potential and achievement. This laboratory study with a large diverse sample used multiple recently established sensitivity and creativity measures while controlling negative-affect and Big-Five personality traits. Only sensitivity and openness correlate positively with three creativity measures and independently predict two (achievement, ideation). Openness predicts creative products and achievement more strongly as sensitivity rises above average, and conversely. Sensitivity and openness primarily determine diverse creative abilities and demonstrate vantage-sensitivity. Developmental environment interacting with neurosensitivity mechanisms (especially lower inhibition), and automatic attention may explain why sensitive, open people are more creative.

Keywords: creativity, temperament, personality, plasticity, adult personality development.

Creativity drives cultural evolution, and experiencing creative flow is associated with positive-affect and well-being, but individuals differ widely in creative ability (Runco, 2014; Sawyer, 2012; Simonton, 2014). Individual differences in cognition, affect, and personality have been explored extensively as factors in creativity, but pinpointing the exact factors has remained elusive (Sawyer, 2012). Sensitivity is a biologically-based personality/temperament dimension (Evans & Rothbart, 2007; Pluess, 2015a) associated with creativity anecdotally but rarely investigated and with mixed results (Martindale, 1999; Martindale, Anderson, Moore, & West, 1996; Necka & Hlawacz, 2013). Critically, recent state-of-the-art sensitivity and creativity assessments have not been used, especially those reflecting recent advances in defining sensitivity (Aron & Aron, 1997; Evans & Rothbart, 2007; Pluess, 2015a). The study addresses this major gap in understanding individual differences in creativity, focusing on sensitivity.

Temperament Frameworks of Sensitivity

Environmental sensitivity refers to variation in the sensitivity of an individual's response to external environmental stimuli, for better or worse, through mechanisms of "neurosensitivity" wherein the central-nervous-system responds more strongly to sensory stimulation in more sensitive individuals (Pluess, 2015a). Neurosensitivity may produce disproportionate susceptibility to negative outcomes (i.e., high negative-affect) following childhood adversity (Aron & Aron, 1997; Aron, Aron, & Davies, 2005; Pluess, 2015a) but simultaneously the potential for disproportionate gain from beneficial environments resulting in positive outcomes (e.g., openness, resilience, creativity), showing "vantage-sensitivity" (Pluess, 2015b). Environmental sensitivity incorporates ideas about sensory-processing sensitivity (SPS; Aron & Aron, 1997), a trait domain characterised by differences in transmitting and processing sensory information that can be measured with the Highly Sensitive Person Scale (HSPS; Aron & Aron, 1997). Neurosensitivity and SPS frameworks overlap with the emotion-attention framework (Evans & Rothbart, 2007, 2008) which defines orienting sensitivity (OS) as sensitivity of the involuntary (exogenous) attention system that is independent from negative-affect-related sensitivity (Evans & Rothbart, 2007, 2008), reflecting a vantage-sensitivity associated with positive outcomes in personality, emotion and well-being (Smolewska, McCabe, & Woody, 2006; Sobocko & Zelenski, 2015).

Orienting sensitivity and negative-affect-related sensitivity reflect different outcomes of the sensitive temperament that can be measured using the Adult Temperament Questionnaire (ATQ; Evans & Rothbart, 2007), and HSPS (Smolewska et al., 2006; Sobocko & Zelenski, 2015), although the HSPS was originally designed to measure SPS as a unidimensional construct (Aron & Aron, 1997). In this study, we investigate how positive and negative-affect-related sensitivity factors predict creativity.

Sensitive Creators.

Early behavioural and physiological experiments linked higher creativity with more sensitive personalities. Martindale and colleagues investigated the hypothesis that creative people are exceptionally sensitive (Martindale, 1999). Creativity is associated with higher sensory sensitivity to sensory stimulation. For example, high versus low creative people rate pain (from electric shock) as more intense, suggesting greater sensitivity to pain (Martindale, 1977), and show greater physiological responses and slower habituation to white noise (Martindale et al., 1996). Creativity is associated with sensitivity to emotion, as people who are biologically sensitive to negative-affect score higher on creative measures than people less vulnerable (Akinola & Mendes, 2008). In personality research, a quantitative meta-analysis shows the most creative individuals tend to be higher in openness, introversion, impulsivity, and display higher sensitivity to internal affective states compared with less creative people (Feist, 1998). However, in this earlier work sensitivity was defined informally and could not benefit from recent definitions and measurements. More recently, Necka and Hlawacz (2013) found no relationship between sensory sensitivity defined and measured using Strelau's Regulative Theory of Temperament and the Test for Creative Thinking-Drawing Production, but they used a small sample (*N*=60) of artists and bankers, and negative-affect was not controlled, which is recommended because negative-affect-related HSPS items may also capture Neuroticism (Aron & Aron, 2013). Using the ATQ (Evans & Rothbart, 2007), Lin and colleagues (2013) found (*N*=320) that OS predicts creative insight but not divergent-thinking measured using the Abbreviated Torrance Test for Adults (ATTA; Goff & Torrance, 2002) whilst controlling for 6-factors of personality (HEXACO), and general intelligence (Ravens). Findings support a "positive-mood-promotes-creativity" hypothesis (Kaufmann, 2003) for sensitivity, but the study did not assess (a) the HSPS and NA, (b) interactions of sensitivity and the Big-Five personality, and (c) overall ATTA score, and (d) Asian versions were used which raises the issue of cultural differences between Asian and Western people affecting performance on creative tasks (for a review, see Niu & Sternberg, 2002) and how sensitivity affects neurocognition (Aron et al., 2010).

Critically, how the different sensitivity dimensions relate to creativity is unknown, but orienting sensitivity may be particularly important as suggested by the theoretical and empirical literature exploring attention in creative cognition. The cognitive disinhibition and hemispheric asymmetry hypothesis describe the creative process as the construction of novel associations from usually-inhibited information (S. Carson, 2014) emerging into conscious awareness via interaction with strongly right-lateralized attention mechanisms. Indeed, right-hemisphere exogenous attention (Corbetta & Shulman, 2002; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005) may benefit creativity as global attentional scopes facilitate access to remotely associated content in memory (Förster & Dannenberg, 2010), which may be useful for global problem restructuring and creative insight (Schooler & Melcher, 1995) and divergent-thinking (Friedman & Förster, 2001). Thus sensitive exogenous attention, as in OS, may facilitate creativity by giving greater awareness of novel associations during disinhibited states. Further, different sensitivity factors (e.g., OS vs. NA) are associated with positive versus negative-affect, respectively (Sobocko & Zelenski, 2015), which are related to creativity in different ways (Sawyer, 2012). For activating mood states (approach vs. avoidance), positive-affect is associated with higher creativity, whereas negative-affect is associated with lower creativity (cf. De Dreu, Baas, & Nijstad, 2008; Kaufmann, 2003). Thus among sensitivity factors, those associated with positive-affect (i.e., OS) may increase creativity, perhaps because global right-lateralized attention states (Corbetta & Shulman, 2002; Fan et al., 2005) associated with positive mood (Wadlinger & Isaacowitz, 2006) foster higher creativity (Förster & Dannenberg, 2010), while those associated with negative-affect (i.e., NA) decrease creativity.

Sensitivity may also have independent and interactive effects on creativity, insofar as sensitivity as a biologically-based construct is distinct from Big-Five personalities (Aron & Aron, 1997) but interacts with genetics and environment to influence the development of cognition, affect and Big-Five traits, including openness, neuroticism and introversion (Aron, Aron, & Jagiellowicz, 2012; Bridges & Schendan, submitted; Evans & Rothbart, 2007; Pluess, 2015a). Indeed, creativity scholarship proposes interactions: “openness interact(s) with a range of behaviors and tendencies, including autonomy, unconventionality, and sensitivity” (p. 282, Runco, 2014).

This study investigated the relationship between sensitivity and creativity, using state-of-the-art measures of each that reflect recent advances, while controlling negative-affect and Big-Five dimensions. (i) The primary hypothesis: different factors of sensitivity have different relationships with creativity. (ii) For positive-affect-related traits, OS improves creativity, and the association between creativity and openness depends on sensitivity (insofar as openness reflects experience interacting with sensitivity and other factors to develop this personality (Bridges & Schendan, submitted; Evans & Rothbart, 2007)). (iii) For negative-affect-related traits, neuroticism and introversion (inverse extraversion) are related to lower creativity, and the association between neuroticism and creativity depends upon NA-related sensitivity factors.

Method

Participants

Stable correlation estimates require sample sizes approaching 250 (Schönbrodt & Perugini, 2013). A diverse sample of 288 (215 female; aged 18-67 years, M=21.05, SD=5.02; education 7–27 years, M=14.93 years, SD=2.18, 84% white) of 297 participants recruited from XXXX students (*n*=252) and local communities (*n*=45), excluding 9 who did not complete, were educated to postgraduate (*n*=8), bachelor's degree (*n*=73), A-level (*n*=170), college/vocational course (*n*=21), GCSE (*n*=3) or other (*n*=13). Participants received £8 per hour or course credit.

Apparatus and Materials

Sensitivity was measured using 1) the full 27-item HSPS (Aron & Aron, 1997), and 2) the 77-item ATQ short-form (Evans & Rothbart, 2007) that measures HSPS-related factors of OS and NA, and two other temperament factors: effortful-control and extraversion/surgency. The 44-item Big-Five Inventory (BFI) measured openness, conscientiousness, extraversion, agreeableness, neuroticism (BFI-O, C, E, A, N, respectively, henceforth) (John & Srivastava, 1999); note, 43 participants completed the full 48-item openness scale of the NEO-PI-R (Costa & McCrae, 1992), which includes all BFI-O items. Openness, neuroticism, and extraversion were relevant to the hypotheses.

Creativity was measured using the ATTA (Goff & Torrance, 2002) consisting of 3×3-minute, figural and verbal tests administered in paper format with pencils and erasers; Creative Achievement Questionnaire (CAQ; Carson, Peterson, & Higgins, 2005) probing objective creative achievement across 10 domains; 19-item Runco Ideation Behavioural Scale (RIBS;

Runco, Plucker, & Lim, 2000-2001) probing behavioural tendencies and abilities about ideas and thinking, emphasizing creative, unusual, or imaginative thought. The ATTA and CAQ are not personality questionnaires and thus avoid common-method bias. Common-method bias is avoided between RIBS and both sensitivity scales because, based on factor analysis testing with a 1-factor solution, models explaining <50% indicate common-method bias is not a problem. For ATQ-OS, the model explains 22%, and common variance using AMOS was 15%. For HSPS, the model explains 20% variance and common variance using AMOS was 21%.

Design and procedure

This study was administered in the lab (a) to include the ATTA, as well as additional pencil and paper and computerized tests as part of five unrelated studies of spatial cognition (study 1: n=43, study 2: n=99, study 3: n=65, study 4: n=80, study 5: n=29), and (b) to ensure participant motivation, compliance, and data integrity compared to prior studies of sensitivity where items were answered online (Sobocko & Zelenski, 2015), at home (Smolewska et al., 2006) or at unspecified locations (Evans & Rothbart, 2008).

This study used within-subjects correlational design. Participants sat at a table in a room with the experimenter. Participants first completed the ATTA and then used a laptop to complete an online computerized battery (surveymonkey.co.uk) using a mouse to select responses that best applied. Each questionnaire was presented on separate webpages in this order: CAQ, RIBS, HSPS, BFI, and ATQ. Participants were instructed that the task was not timed, to complete the questionnaires in their own time, and to give honest answers.

Analysis

HSPS items were analysed in full and split according to factors of sensitivity. Based on the 2-factor solution (Evans & Rothbart, 2008), 7 items measured OS (HSP-OS), and 18 items measured NA (HSP-NA). For the 3-factor solution (Smolewska et al., 2006), 12-items measured ease-of-excitation (HSP-EOE), 6-items measured low-sensory-threshold (HSP-

LST), and 7 items measured aesthetic sensitivity (labelled HSP-OS/AS because 5 of 7 items are common to the HSP-OS factor (Sobocko & Zelenski, 2015)). For the ATQ, we focused on the two factors associated with the HSPS: OS (ATQ-OS) and NA (ATQ-NA). As recommended for HSPS research, NA was controlled using ATQ-NA, and the BFI-N, which both assess trait negative-affect (Aron et al., 2012). We also considered extraversion, which has weaker links to creativity than openness (Sawyer, 2012) and is inversely associated with sensitivity based on the HSPS (Aron et al., 2012; Sobocko & Zelenski, 2015). Dichotomous analysis was performed (supplemental-material) as theoretical perspectives suggest sensitivity is a taxon (Aron et al., 2012). Factor analyses (supplemental-material) evaluated the HSPS alone, with ATQ-OS, and with ATQ-OS and BFI-O. Overall, results demonstrated discriminant validity between OS, NA, and openness and further evidence for 2 and 3 factor HSPS models.

Missing data were replaced with mean scores across included participants for each item. Next, variables were scaled between 0 and 1 (see Table 1 notes for scaling equations). Assumptions of linear regression were checked (e.g., normality) and non-parametric analysis was used where appropriate. For regression, sensitivity and BFI personalities were regressed onto each creativity measure. Moderated regressions were performed using PROCESS (Hayes, 2013). To counteract problems of multiple testing with several regression models, the Bonferroni Correction (α/m) determined significance, where α=.05 and m=3 measures of creativity set α=.017.

Results and Discussion

Exploratory Correlations

Table 1 summarizes descriptive statistics and non-parametric correlations that temperament and personality measures have with creative achievement, ideation and divergent-thinking/products. Non-parametric correlations were performed as only HSP-NA and HSP–EOE, ATQ-OS and ATQ–NA were normally-distributed (Kolmogorov-Smirnov test, $p>.05$). See supplementary-material for correlations between personality and temperament variables.

"Insert [Table 1 here]"

Creativity and personality. CAQ and RIBS correlated highly positively only with all three measures of OS (ATQ-OS, HSP-OS, and HSP-OS/AS) and with openness, whereas ATTA showed small positive correlations only with ATQ-OS and openness.

Creativity. RIBS was weakly positively correlated with CAQ and ATTA. CAQ was weakly positively correlated with ATTA.

Regression

The correlations confirmed that orienting sensitivity (especially for ATQ-OS) and openness, which are positive-affect-related factors (Sobocko & Zelenski, 2015), are most consistently positively related to creativity, supporting the primary hypothesis. Model 1 tested the hypotheses that sensitivity and openness predict creativity using all Big-Five factors and ATQ-OS and NA. The two-factor sensitivity model was selected because this emerged as the most consistent solution in factor analysis using HSPS, ATQ-OS and openness items (supplementary-material). In Model 2, hierarchical multiple regression helped identify and remove redundant variables, and Model 3 used moderated regression to determine potential interactions.

"Insert [Table 2 here]"

Model 1. Fits were significant for creative achievement (CAQ): $F(7,280)=11.58$, $p<.001$, $R^2=.21$; Ideation (RIBS): $F(7,280)=25.87$, $p<.001$, $R^2=.38$; Products (ATTA): $F(7,280)=3.02$, $p<.01$, $R^2=.05$. OS and openness explain unique variance in CAQ and RIBS. Regarding ATTA, openness and conscientiousness were significant (see Table 2).

Refined model 2. Model 1 was simplified by removing non-significant personality covariates: Extraversion, agreeableness and conscientiousness were removed in that order, and model fits assessed at each change. To control negative-affect (Aron & Aron, 2013), ATQ-NA and neuroticism were always retained.

For CAQ and RIBS, no significant differences in model fit occurred at any stage (*p*s>.1). Thus ATQ-OS and ATQ-NA, openness and neuroticism were retained. For the ATTA, removing extraversion and agreeableness did not change model fits (*p*s>.1), however removing conscientiousness changed the model significantly, $F(1,282)=7.99$, $p<.01$, so conscientiousness was retained. Table 2 summarizes results for model 2. For each creativity measure, changes in fit between models 1 and 2 were not significant (*ps*>.28).

Model 2 fits were significant for CAQ: $F(4,283)=19.49$, $p<.001$, $R^2=.21$; RIBS: $F(4,283)=44.31$, $p<.001$, $R^2=.38$; ATTA: $F(5,282)=3.72$, $p<.01$, $R^2=.05$. For CAQ and RIBS, ATQ-OS was a unique predictor. For ATTA, openness and conscientiousness were unique predictors.

Moderated regression: Model 3. Moderated regression assessed whether openness coefficients vary with sensitivity. Model 3 added the interaction term (BFI-O×ATQ-OS) to Model 2. Mean-centred variables were used to reduce potential multicollinearity between predictor variables. Using PROCESS (Hayes, 2013), simple-slopes analysis assessed interactions (Aiken & West, 1991), and significant interactions were probed using the Johnson-Neyman (1936) technique, eliminating the need to define arbitrary categories (e.g., low, high) from continuous moderator values (Hayes, 2013). Table 2 summarizes results and Figure 1 plots the interaction term and points among ATQ-OS values where conditional effects of openness on creativity became significant (CAQ, ATTA) or not (RIBS). To interpret interactions neutrally, all model 3 analyses were performed with ATQ-OS as a predictor of creativity, as moderated by openness (supplemental-material).

CAQ. Fit was significant, $F(5,282)=13.14$, $p<.001$, $R^2=.25$, and significantly ~4% higher than model 2, $F(1,282)=4.9$, $p=.028$. Both ATQ-OS and openness explained unique variance with the interaction term included, which itself was significant. The conditional effect of openness on CAQ became significant at scaled ATQ-OS values -.17 below the mean, $b=.12$, $t(282)=1.97$, $p=.05$, and above, which includes 89.58% of participants. One caveat, the CAQ distribution violates assumptions of parametric tests, and robust Poisson regression or log10 transforms (yielding the most normal distribution, although Shapiro-Wilks test is significant, $p=.044$) reveal independent effects but not the interaction.

RIBS. Fit was significant, $F(5,282)=36$, $p<.001$, $R^2=.39$, but non-significantly higher than model 2, $F(1,282)=.386$, $p=.535$. Both ATQ-OS and openness were significant with the interaction term included. The interaction was not significant. Thus openness and ATQ-OS independently predict RIBS.

ATTA. Fit was significant, $F(6,281)=4.47$, $p<.001$, $R^2=.07$, and significantly ~1% higher than model 2, $F(1,281)=5.57$, $p=.017$. Openness, conscientiousness and the interaction term were significant. Critically, the interaction term was significant at average levels of ATQ-OS and above. The conditional effect of openness on ATTA became significant at scaled ATQ-OS values -.04 below the mean, $b=.113$, $t(281)=1.97$, $p=.05$ and above, which includes 61.46% of participants.

"Insert [Figure 1 here]"

Negative-affect. Results provided no evidence for the third hypothesis about negative-affect-related traits and creativity. As no correlations between NA components and creativity were found (Table 1), no moderated regression analysis is reported.

General Discussion

Overall, OS and openness, independently and/or interactively, underlie individual differences in multiple creative processes. No support was found for the third hypothesis that

NA factors are related to creativity, consistent with the conclusion that OS is independent of NA and negative-affect-related personality (Evans & Rothbart, 2007, 2008). Supporting the first hypothesis, only higher OS and openness are associated with higher creativity on all 3 measures. Further, only OS and openness independently predict creative achievement (CAQ) and ideation (RIBS). Supporting the second hypothesis, when OS is about average and higher, openness increases creative achievement and products (ATTA). The results show for the first time that OS promotes multiple creative processes using both ATQ and HSPS (supplementary-material) in a large diverse adult sample, while controlling negative-affect, providing needed evidence for vantage-sensitivity. Using dichotomous sensitivity variables (i.e., sensitive vs. non-sensitive groups; supplementary-material) creativity is higher in sensitive versus non-sensitive groups, as high ATQ-OS groups have higher CAQ scores, and, if openness is higher, both higher CAQ (ATQ-OS) and RIBS (HSPS group). Thus, highly sensitive people are more creative, whether sensitivity is treated as a continuous or dichotomous variable.

Previous evidence of vantage-sensitivity includes observations of higher openness (using HSPS and ATQ) (Evans & Rothbart, 2008; Sobocko & Zelenski, 2015), positive-affect (using HSPS) (Sobocko & Zelenski, 2015), and creative insight (using ATQ) (Lin et al., 2013) in sensitive adults. The first empirical evidence for vantage-sensitivity is the observation of greater responsiveness to mental-health interventions in 11 year-old girls with high but not low sensitivity (using 12-item child version of HSPS) (cf. Aron et al., 2005; Pluess & Boniwell, 2015).

Altogether, the findings implicate different processes in different creativity measures. First, all creativity measures correlate but only moderately between achievement and ideation, which are weakly related to products; note, a prior study found ATTA originality correlated with CAQ arts but reported no significant correlation between total scores of CAQ achievement and ATTA products (Zabelina, Colzato, Beeman, & Hommel, 2016) perhaps due to smaller sample size (*N*=100) yielding lower statistical power (Schönbrodt & Perugini, 2013). Second, (a) OS and openness predict creative ideation only independently, and (b) achievement independently and interactively, and (c) openness predicts products alone and interactively with OS. Altogether, these findings suggest at least three personality-related processes underlie creativity: one for openness, a second for OS, and a third OS-openness interaction process that enables OS to influence the effect of openness on products and achievement. Notably, this provides further evidence that multiple cognitive, personality and other individual differences contribute to real-world creative achievement (Carson et al., 2005; Jauk, Benedek, & Neubauer, 2014), adding sensitivity to this list.

Sensitive, Open People Are More Creative

Bridges and Schendan (submitted) suggest that cognitive disinhibition and hemispheric asymmetry explain the sensitivity-creativity relationship. Sensitive individuals whom tend to experience positive environments gain benefits of higher creativity primarily through mechanisms of openness (with resilience), disinhibition (neurosensitivity via reduced inhibition) and/or sensitive orienting to novelty. Disinhibition and involuntary attention underlie latent inhibition (Lubow & Gewirtz, 1995), a phenomenon implicated in creative personalities. Latent inhibition is the reduction in learning wherein familiar stimuli enter new associations more slowly than novel stimuli, so, when latent inhibition is lower, learning improves. Lower latent inhibition is associated with higher openness (Lubow & Gewirtz, 1995; Peterson & Carson, 2000) and higher creative achievement, especially in highly intelligent people, suggesting creative people are more open to environmental stimuli (Carson, Peterson, & Higgins, 2003). Critically, low latent inhibition manifests as “leaky” attention, which itself is associated with higher creativity (Zabelina, O'Leary, Pornpattananangkul, Nusslock, & Beeman, 2015). Low latent inhibition and leaky attention can explain early work linking higher sensitivity to less habituation to white noise, divergent thinking, and higher skin conductance response (Martindale et al., 1996) indexing automatic attention orienting response to irrelevant (and novel) stimulation (Bradley, 2009). We hypothesize that latent inhibition underlies the sensitive creator, although experimental work is needed.

Limitations

OS captures a biologically-based core of openness (Shiner & DeYoung, 2013), in part based on their correlations (Evans & Rothbart, 2007). Limitations of factor analysis used in this study (supplementary-material) cannot determine whether OS and openness are independent, or different levels of the same conceptual hierarchy, i.e., one general factor and one subfactor (Evans & Rothbart, 2008). The independence of OS and openness as predictors of creativity is further conflated due to our use of short-form ATQ-OS and BFI-O, for which incremental predictive validity needs to be determined. However, 43 subjects completed long-forms of the NEO-PI-R openness, and, despite the small sample, ATQ-OS still explains unique variance in RIBS when controlling negative-affect and openness ($p<.01$) which itself explains no unique variance. Another limitation is that recent work found strong support for a bifactor structure of the HSPS composed of the three HSPS factors (OS/AES, EOE, LST) and one general factor (Lionetti et al., 2018). While this was not explored here in confirmatory factor analyses (supplemental-material), the present results support the conclusion of 3 distinct sensitivity factors among which OS explains the sensitivity-creativity association, and analyses with the full HSPS did not yield stronger relations with creativity than OS alone.

Future Directions

The concept of neurosensitivity (Aron & Aron, 1997; Evans & Rothbart, 2007; Pluess, 2015a) suggest a neurocognitive basis of this biologically-based trait. Thus, we hypothesize sensitivity has broad implications for perception, attention, learning and memory that impact creativity. Future work should establish how self-report measures of sensitivity relate to objective cognitive measures, including exogenous attention and latent inhibition, and how these objective measures relate to creativity. This work will inform sensitivity frameworks, helping to refine and compliment self-report sensitivity measures, whilst improving knowledge and understanding of the brain basis for creativity in sensitive creators. Further work should also determine the incremental predictive validity of OS over openness when accounting for variance in creativity measures by using long-form measures in tandem with creativity scales.

Conclusions

In sensitivity, positive environments lead to vantage-sensitivity and higher creativity primarily through mechanisms of openness with resilience, disinhibition (neurosensitivity via reduced inhibition) and/or sensitive orienting to novelty. In a Western society that favours "tough warriors and kings", sensitivity is perceived as flaw, and is thus penalized (Aron, 1999). In this study, we demonstrate that sensitivity should be valued and nurtured because positive-affect-related sensitivity traits of OS, and openness have major roles in a wide range of creative cognitive abilities relating to achievement, ideation, divergent-thinking and insight, each important for cultural advancement.

Conflict of Interest: The authors declare no competing financial interests.

Acknowledgments: Both authors contributed equally and share primary authorship: 2 conceived the idea to investigate sensitive temperament, openness, and creativity and designed the initial study; 1 and 2 designed study 2-5; 1 analysed the data; 1 and 2 prepared the manuscript. The authors are grateful to Viktoria Vianeva, Christopher Jones, Michelle Hurley, Matthew Wilson, Zoi Toutountzidou, Alice Miller, Jeannie Morrice, and Michaela Grochova for assistance with data collection, Dr. Alison M. Bacon for recommending the Big Five Inventory. Funding provided by Plymouth University Ph.D. Studentship to 1; COGNOVO EU FP7-PEOPLE-2013-ITN-604764 to 1 and 2, COGNITSIMS EU FP7-PEOPLE-2011-CIG-294144 to 2, and Faculty Innovation Centre (FInC) Grant from Plymouth University to 2.

References

Akinola, M., & Mendes, W. B. (2008). The dark side of creativity: biological vulnerability and negative emotions lead to greater artistic creativity. *Pers Soc Psychol Bull, 34*(12), 1677-1686.
Aron, A., Ketay, S., Hedden, T., Aron, E. N., Rose Markus, H., & Gabrieli, J. D. (2010). Temperament trait of sensory processing sensitivity moderates cultural differences in neural response. *Social cognitive and affective neuroscience, 5*(2-3), 219-226.
Aron, E. N., & Aron, A. (1997). Sensory-Processing Sensitivity and Its Relation to Introversion and Emotionality. *Journal of Personality and Social Psychology, 73*(2), 345-368.
Aron, E. N., & Aron, A. (2013). *TIPS for SPS Research*. www.hsperson.com.
Aron, E. N., Aron, A., & Davies, K. M. (2005). Adult shyness: the interaction of temperamental sensitivity and an adverse childhood environment. *Pers Soc Psychol Bull, 31*(2), 181-197.
Aron, E. N., Aron, A., & Jagiellowicz, J. (2012). Sensory processing sensitivity: a review in the light of the evolution of biological responsivity. *Pers Soc Psychol Rev, 16*(3), 262-282.
Bradley, M. M. (2009). Natural selective attention: orienting and emotion. *Psychophysiology, 46*(1), 1-11.
Bridges, D., & Schendan, H. E. (submitted). Sensitive Individuals are More Creative.
Carson, S. H., Peterson, J. B., & Higgins, D. M. (2003). Decreased latent inhibition is associated with increased creative achievement in high-functioning individuals. *J Pers Soc Psychol, 85*(3), 499-506.
Carson, S. H., Peterson, J. B., & Higgins, D. M. (2005). Reliability, validity, and factor structure of the creative achievement questionnaire. *Creativity Research Journal, 17*, 37-50.
Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nat Rev Neurosci, 3*(3), 201-215.
Costa, P. T., & McCrae, R. R. (1992). Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI) professional manual. Odessa, FL: Psychological Assessment Resources.
De Dreu, C. K., Baas, M., & Nijstad, B. A. (2008). Hedonic tone and activation level in the mood-creativity link: toward a dual pathway to creativity model. *J Pers Soc Psychol, 94*(5), 739-756.
Evans, D. E., & Rothbart, M. K. (2007). Developing a model for adult temperament. *Journal of Research in Personality, 41*, 868-888.
Evans, D. E., & Rothbart, M. K. (2008). Temperamental sensitivity: Two constructs or one? *Personality and Individual Differences, 44*(1), 108-118.
Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I., & Posner, M. I. (2005). The activation of attentional networks. *Neuroimage, 26*(2), 471-479.
Förster, J., & Dannenberg, L. (2010). GLOMOsys: A systems account of global versus local processing. *Psychological inquiry, 21*(3), 175-197.
Friedman, R. S., & Förster, J. (2001). The effects of promotion and prevention cues on creativity. *Journal of Personality and Social Psychology, 81*(6), 1001.
Goff, K., & Torrance, E. P. (2002). Abbreviated Torrance Test for Adults manual. Bensenvill, IL: Scholastic Testing Service.

Jauk, E., Benedek, M., & Neubauer, A. C. (2014). The Road to Creative Achievement: A Latent Variable Model of Ability and Personality Predictors. *Eur J Pers, 28*(1), 95-105.
John, O. P., & Srivastava, S. (1999). The Big Five trait taxonomy: History, measurement, and theoretical perspectives. *Handbook of personality: Theory and research, 2*(1999), 102-138.
Kaufmann, G. (2003). Expanding the mood-creativity equation. *Creativity Research Journal, 15*, 131-135.
Lin, W.-L., Hsu, K.-Y., Chen, H.-C., & Chang, W.-Y. (2013). Different attentional traits, different creativities. *Thinking Skills and Creativity, 9*, 96-106.
Lionetti, F., Aron, A., Aron, E. N., Burns, G. L., Jagiellowicz, J., & Pluess, M. (2018). Dandelions, tulips and orchids: evidence for the existence of low-sensitive, medium-sensitive and high-sensitive individuals. *Translational Psychiatry, 8*(1), 24.
Lubow, R. E., & Gewirtz, J. C. (1995). Latent inhibition in humans: data, theory, and implications for schizophrenia. *Psychological bulletin, 117*(1), 87.
Martindale, C. (1977). CREATIVITY, CONSCIOUSNESS, AND CORTICAL AROUSAL. *Journal of Altered States of Consciousness, 3*(1), 69-87.
Martindale, C. (1999). Biological bases of creativity. In R. J. Sternberg (Ed.), *Handbook of Creativity* (pp. 137-152). Cambridge, UK: Cambridge University Press.
Martindale, C., Anderson, K., Moore, K., & West, A. N. (1996). Creativity, oversensitivity, and rate of habituation. *Personality and Individual Differences, 20*(4), 423-427.
Necka, E., & Hlawacz, T. (2013). Who has an Artistic Temperament? Relationships Between Creativity and Temperament Among Artists and Bank Officers. *Creativity Research Journal, 25*(2), 182-188.
Niu, W., & Sternberg, R. (2002). Contemporary studies on the concept of creativity: The East and the West. *The Journal of Creative Behavior, 36*(4), 269-288.
Peterson, J. B., & Carson, S. H. (2000). Latent Inhibition and Openness to Experience in a high-achieving student population. *Personality and Individual Differences, 28*, 323-332.
Pluess, M. (2015a). Individual Differences in Environmental Sensitivity. *Child development perspectives, 9*(3).
Pluess, M. (2015b). Vantage Sensitivity: Environmental Sensitivity to Positive Experiences as a Function of Genetic Differences. *J Pers*.
Pluess, M., & Boniwell, I. (2015). Sensory-Processing Sensitivity predicts treatment response to a school-based depression prevention program: Evidence of Vantage Sensitivity. *Personality and Individual Differences, 82*, 40-45.
Runco, M. A. (2014). *Creativity: Theories and Themes: Research, Development, and Practice* (Second ed.): Elsevier, Inc.
Runco, M. A., Plucker, J. A., & Lim, W. (2000-2001). Development and psychometric integrity of a measure of ideational behavior. *Creativity Research Journal, 13*(3 & 4), 393–400.
Sawyer, R. K. (2012). *Explaining creativity: The science of human innovation* (Second ed.). New York: Oxford University Press, Inc.
Schönbrodt, F. D., & Perugini, M. (2013). At what sample size do correlations stabilize? *J Res Pers, 47*(5), 609-612.
Schooler, J. W., & Melcher, J. (1995). The ineffability of insight. *The creative cognition approach*(Cambridge, MA, US: The MIT Press), (pp. 97-133).
Shiner, R. L., & DeYoung, C. G. (2013). The structure of temperament and personality traits: A developmental perspective. In P. D. Zelazo (Ed.), *The Oxford Handbook of Developmental Psychology* (Vol. 2, pp. 113-141). Oxford: Oxford University Press.

Simonton, D. K. (2014). Can creative productivity be both positively and negatively correlated with psychopathology? Yes! *Front Psychol, 5*, 455.
Smolewska, K. A., McCabe, S. B., & Woody, E. Z. (2006). A psychometric evaluation of the Highly Sensitive Person Scale: The components of sensory-processing sensitivity and their relation to the BIS/BAS and ''Big Five''. *Personality and Individual Differences, 40*, 1269–1279.
Sobocko, K., & Zelenski, J. M. (2015). Trait sensory-processing sensitivity and subjective well-being: Distinctive associations for different aspects of sensitivity. *Personality and Individual Differences, 83*, 44-49.
Wadlinger, H. A., & Isaacowitz, D. M. (2006). Positive mood broadens visual attention to positive stimuli. *Motivation and emotion, 30*(1), 87-99.
Zabelina, D. L., Colzato, L., Beeman, M., & Hommel, B. (2016). Dopamine and the Creative Mind: Individual Differences in Creativity Are Predicted by Interactions between Dopamine Genes DAT and COMT. *PLoS One, 11*(1), e0146768.
Zabelina, D. L., O'Leary, D., Pornpattananangkul, N., Nusslock, R., & Beeman, M. (2015). Creativity and sensory gating indexed by the P50: selective versus leaky sensory gating in divergent thinkers and creative achievers. *Neuropsychologia, 69*, 77-84.

Table 1

Spearmans Rho correlations and descriptive statistics

		Creativity			*Descriptive*		
		CAQ	RIBS	ATTA	R. µ	S. µ	SD
Creativity							
Creative Achievement Questionnaire	CAQ	-			9.61	.11	1.00
Runco Ideational Behaviour Scale	RIBS	.343***	-		2.95	.49	.68
Abbreviated Torrance Test for Adults	ATTA	.153**	.279***	-	67.86	.74	.85
Temperament factors							
Highly-Sensitive Person Scale	HSPS	.247***	.300***	.083	4.15	.53	.77
Orienting Sensitivity	HSP-OS	.410***	.489***	.201***	4.44	.57	.81
Negative Affect	HSP-NA	.153**	.186**	.019	4.05	.51	.79
Orienting/Aesthetic Sensitivity	HSP-OS/AS	.459***	.555***	.236***	4.42	.57	.92
Ease-of-excitation	HSP-EOE	.093	.171**	-.007	4.51	.59	.78
Low-sensory-threshold	HSP-LST	.185**	.187***	.072	3.43	.40	.95
Adult Temperament Questionnaire	ATQ						
Orienting Sensitivity	ATQ-OS	.442***	.561***	.201***	4.58	.60	.13
Negative Affect	ATQ-NA	.072	.095	.031	4.09	.51	.12
Effortful Control	ATQ-EC	-.112	-.177**	.105	3.90	.48	.78
Extraversion/Surgency	ATQ_ES	.100	.064	-.075	4.61	.60	.68
Big-Five Inventory of Personality	BFI						
Openness	BFI-O	.456***	.530***	.253***	3.24	.56	.85
Conscientiousness	BFI-C	-.109	-.117*	.084	3.38	.59	.94
Extraversion	BFI-E	.123*	.103	.046	3.26	.56	.91
Agreeableness	BFI-A	.010	-.058	-.158**	3.76	.69	.75
Neuroticism	BFI-N	.086	.113	.083	3.17	.54	1.00

Note. 2-tailed significance: * $p < 0.05$ level, ** $p < .01$, *** $p < .001$. R.µ = Raw mean score. S.µ = Scaled mean score. SD = standard deviation for scaled scores. Raw ATQ and HSPS scores = (score*6)+1, raw personality and RIBS scores = (score*4)+1, raw ATTA scores = score*92, raw CAQ scores = score*86.

Table 2

Regression models 1-3 predicting creative achievement (CAQ), creative ideation (RIBS), and creative products (ATTA)

	CAQ	RIBS	ATTA
	Beta	Beta	Beta
Model 1			
ATQ-OS	.163*	.343***	.030
ATQ-NA	.023	.056	-.022
BFI-O	.329***	.324***	.163*
BFI-C	-.091	-.032	.182**
BFI-E	.044	.089	.029
BFI-A	.000	-.034	-.092
BFI-N	-.017	.024	.120
Refined model 2			
ATQ-OS	.168*	.345***	.023
ATQ-NA	.008	.039	-.018
BFI-O	.343***	.338***	.171*
BFI-N	-.016	.003	.115
BFI-C	-	-	.166*
Moderated regression model 3			
ATQ-OS	.135*	.35***	.005
BFI-O	.362***	.335***	.18*
ATQ-OS × BFI-O	.171*	-.024	.09*
ATQ-NA	-.03	.044	-.038
BFI-N	.008	0	.127
BFI-C	-	-	.162*

Note. * $p<.05$, ** $p<.01$, *** $p<.001$. Beta = standardized coefficients.

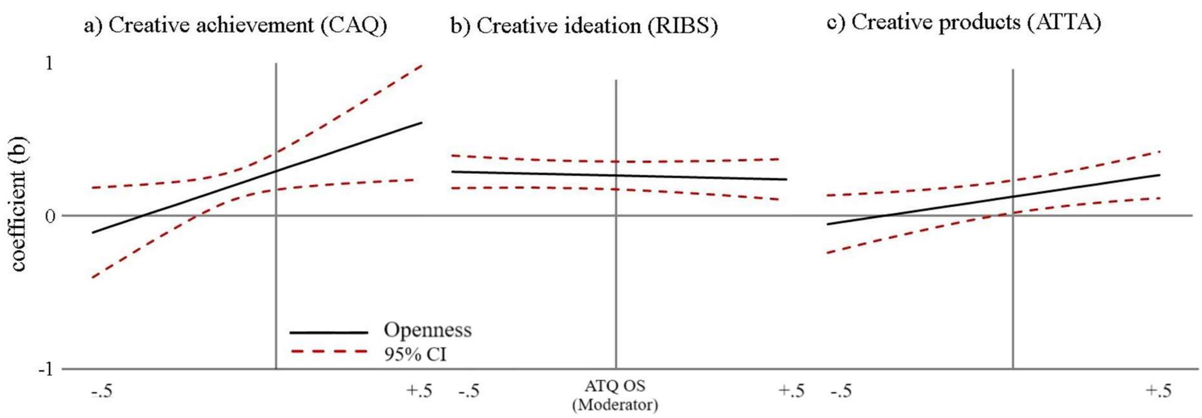

Figure 1. Model 3 conditional effects of openness on a) creative achievement (CAQ), b) creative ideation (RIBS), and c) creative products (ATTA) by levels of orienting sensitivity (x-axis) controlling for negative affect.