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In the Blink of an Eye: Ocular Proxies of Neurotransmitters Predict Creative Ability

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Abstract Previous research suggests that eye blink rates (EBR) can be used as an index for dopamine activity (DA) and therefore a potential marker of creative aptitude. In addition, another putative index of creativity has been linked to the neurotransmitter serotonin (5-HT) and eye blink duration (EBD). The current pilot study aimed to investigate whether both EBR and EBD could be used as predictors of creativity and if mood would influence these measures. Vertical electrooculograms were gathered from 12 participants, during three conditions, to enable subsequent EBR and EBD to be calculated. The three conditions comprised eyes open baseline, viewing images from the International Affective Picture System (IAPS) of positive and finally negative valence. Dispositional measures of creativity were measured post task using the Creative Styles Questionnaire-revised. Higher EBR was significantly related to higher scores on subcategories 'Use of Techniques' and 'Use of Other People'. In addition, shorter EBD significantly correlated with higher scores of global creativity, 'Use of Techniques' and 'Use of the Senses'. Results confirm that EBR and EBD can be used as predictors for creativity and may reflect DA/5-HT activity. Implications of the results are discussed in relation to specific characteristics, techniques and underlying mechanisms of creativity and how neurotransmitters drive such ability.

Keywords: *dopamine, serotonin, eye blinks, emotion, creativity, mood, IAPS*

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1. Introduction

Creativity is notoriously surrounded by ambiguity and is difficult to define, both in terms of products as a result of creative output and the underlying creative processes which are engaged [1,2]. There were early suggestions that variables such as 'creative behaviour' should be measured [3] using tasks such as Maier's [4] two string problem. Indeed, these early tasks are able to capture a number of key characteristics which can contribute or interfere with creativity and problem solving ability. Similarly, in the cognitive domain other 'paper and pencil' assessments such as the Unusual Uses Task (e.g. [5]) and the Remote Associations paradigm (e.g. [6]) have been influential in capturing key cognitive components of creativity. However, more recently, neuroimaging and electrophysiological methodologies have been implemented alongside paper and pencil psychological tasks in an attempt to capture the underlying neuro-cognitive processes involved in creativity (e.g. EEG, [7]; fMRI, [8]) and has led to the assumption that multiple processes and neural networks are involved (e.g. [9,10]. Here, we contribute to the recent developments in the neuroscience by examining eye blink metrics of neurotransmitters dopamine and serotonin and their link to creative ability.

Some neural pathways suspected to play a role in creativity are those which involve the neurotransmitter dopamine (DA). This connection is highlighted through Eysenck's [11] suggestion that patients with schizophrenia tend to have enhanced creative ability. Eysenck proposed that their cognitive style and in particular disinhibited thinking drives their creative ability, which can also be observed in other populations with such a cognitive profile (e.g. autism and inhibition deficits). On a psychobiological level, the prefrontal cortex an area of the brain associated with creativity is heavily reliant on DA regulation and is thought to subserve a number higher order cognitive functions such as inhibition [12,13]. There is a wide history of pharmacological, post-mortem and imaging evidence that schizophrenia can be associated with DA transmitter hyperactivity and greater receptor binding which underlie the 'positive' symptoms (see [14] for a review; [15]) resulting in enhanced creative ability. These are often treated with antipsychotic drugs which are designed to act as antagonists of DA D2 receptors [16]. As such, it is reasonable to consider a link between creativity and DA and that healthy individuals may have a similar, but non-intrusive, escalated DA activity. Higher levels of DA in healthy individuals could be due to genetic predisposition to D2 receptor dysregulation [11,16] and may explain why creativity often runs in families [17,18]. In a similar vein, it has been noted that Parkinson's

patients have a tendency to flourish in artistry and creative thinking after beginning dopaminergic treatment [19,20].

Positive mood has been associated with higher levels of DA and as a result have a positive effect on creative problem solving [21]. Ashby & Isen [21] proposed that with higher DA comes greater cognitive flexibility and less inhibition of conflicting and alternative thoughts. Positive mood (in terms of happiness) has been seen to elicit enhanced creativity [22]. This suggests a link between mood, DA - and consequently, creativity. Studies looking at mood disorders have also given insight to mood's influence on creativity, with notions of links between creative activity and hypomania [23] and studies indicating a relationship between bipolar disorder and creativity [24,25]. The aforementioned work provided the impetus for the additional manipulation in the current investigation where we seek to establish the link between DA and creativity in intact individuals.

Spontaneous eye blink rates (EBR) has been a widely accepted biological marker of central dopaminergic functioning [26], with studies showing that spontaneous EBR correlate with dopamine levels [27]. Kleven & Koek, [28] demonstrated that cynomolgus monkeys show a significant dose-related EBR increase from direct DA agonists. Similarly, patients with schizophrenia have been shown to have elevated EBR [29], and raised DA uptake within the striatum is evident [30]. Higher EBR have also been observed in children carrying out a task which involves working memory (WM; verbal recall; [31]; DA activity has been known to play a role in WM processes [32], providing further support for the EBR-DA connection. Parkinson's patients have decreased EBR [33] and decreased DA activity in the nigral area of the brain – a dopamine producing area associated with the disease [34] as well as degenerated striatal DA activity [35]. Decreased EBR has also been seen in chronic cannabis users [36] and recreational cocaine users [37] – a drug which disinhibits dopamine neurons, especially with chronic use [37]. Together, these studies demonstrate spontaneous eye blink rates are a reliable biomarker for DA activity. Given the evidence to suggest a link between DA and creativity, it is reasonable to assume that EBR would also be useful as a marker for creativity.

Little attention has been given to the role serotonergic systems (5-HT) in creativity. The putative role of serotonin however has been demonstrated in an influential study linking a number of candidate genes to creative ability. That is, Reuter et al. [38] reasoned if dopamine and serotonin have previously been link to key aspects of cognition (e.g. executive function, memory) investigating possible genes associated with creative ability is also a worthwhile endeavour. In addition to the dopamine DRD2 receptor gene, the serotoninergic gene (TPH1) was significantly associated with a total creativity score made up of tasks measuring flexibility, imagination and other key components of creativity (no association was found with the COMPT gene). A further study provides more evidence of the participation of the central serotonin system in creativity regulation [39]. The researchers suggest that serotonin transporter (5-HTT) impairments can increase risk of depression and that creativity is related to 5-HTT regulated cognitive abilities in the pre-frontal cortex. This bares likeness to the role that DA is often said to play in creativity within literature [40]. Slaby [41] suggested that some of the changes within the serotonergic system associated with depression could also be accountable for risk taking which represents ingenuity in a person who is 'psychodynamically predisposed to being creative' (p. 1). Serotonin has been linked to sleep regulation [42,43,44,48,49,50,51] and sleep loss has been shown to impair performance on divergent thinking tasks [49]. EBD has been demonstrated as an indicator of sleepiness [50,51] and as serotonin is associated with sleep, EBD is worthwhile to investigate as a potential biological marker of serotonin.

The current pilot study primarily looks to further investigate the link between DA and creativity and to use spontaneous EBR as a biological marker for DA levels in order to predict creativity. In addition, we aim to address the gap in literature surrounding a potential additional biomarker of creativity and tentatively investigate the possibility that EBD could be used to predict creativity. To capture the dispositional aspects of creativity, the current study will use the Creativity Styles Questionnaire-Revised (CSQ-R; [52]. The influence of stress on EBR has been previously recognised [53] and mood may also play a role in DA levels and creativity [21,22]. Chermahini and Hommel [53] also found that individuals' EBR were reflective of the impact of mood manipulation on their creative performance. The methods implemented in the current study will follow this lead and use mood as a manipulation for DA levels in order to attempt to help account for mood influences on DA and EBR in addition to exploring differences in blinks between positive and negative mood states, to add to evidence for a DA-EBR connection. It is expected that those who are highly creative will exhibit both overall higher EBR and shorter EBD than less creative individuals. Additionally, as lower mood is generally associated with lower DA and 5-HT activity [54,55] it is predicted that EBR will be lower and EBD be longer in the negative mood manipulation condition than in the positive mood

2. Method

2.1. Participants

Twelve participants were recruited for the study, aged between 21 and 50 years, (M = 34; SD = 11.5) consisting of students and full time workers, with an equal ratio of both males and females. Participants were to be allocated to either the high or low creativity group post-testing, depending on their responses to the CSQ-R. This study was approved by the Department of Psychology, Northumbria University Ethics committee. Participants were invited to take part in the study via email and verbal invitation with a brief description of what the study would involve. All participants provided written consent.

2.2. Materials

The Creativity Styles Questionnaire-Revised [52] was used to assess individual differences in beliefs and strategies regarding creativity. For example, 'I consider myself to be a creative person' and 'I work most

creatively when I have deadlines.' The various creative components that can be extracted from the CSQ-R; these are 'Global Measure of Creativity Capacity', 'Belief in Unconscious Processes', 'Use of Techniques', 'Use of other people', 'Final Product Orientation', 'Environmental Control/Behavioural Self-Regulation', 'Superstition' and 'Use of the Senses'. The BioSemi ActiveTwo System (Biosemi.com) was used to gather vertical electrooculograms (EBR and EBD). A total of 240 (120 rated negative and 120 rated positive) images from the International Affective Picture System (IAPS; [56]) were comprised for the image conditions.

2.3. Procedure

Participants were asked to sit in front of the computer running the E-prime software (Psychology Software Tools, Inc.), with obstructed view of the second computer running the Actiview604 software to gather vertical electrooculograms from the left eye. Once the electrodes were set up the participant was then presented with the visual stimuli on their computer screen and given a verbal brief of the nature of the upcoming task and asked to relax and try to keep still. A crosshair was firstly presented as a general focus point for two minutes. This task was used to attain a baseline measure for the EBR and EBD in order to take into account the natural individual differences in blink activity for subsequent analysis. Participants were then presented with a variety of images consisting of 1 image per second for a total of 4 minutes; a 2-minute series of negative images and a 2-minute series of positive. The order in which the images were presented was randomised. A second crosshair spot focus point was then presented for a further 2 minutes to gain a second baseline EBR measure. EBR and EBD were recorded throughout the entire task. Finally, participants completed the CSQ-R. Recorded blink rates and blink duration were counted and measured through Scan4 editor and questionnaires were scored according to Kumar et al. [52] guidelines. It was taken into account that there could be potential overlap of EBR and EBD responses between conditions and compromise accuracy in the data, therefore only the blink data for the latter minute for each condition (for both baselines and moods) was used for analysis.

3. Results

An initial paired samples T-test was used to identify any difference between the first baseline (baseline 1) and the last base line (baseline 2) measures for EBR/EBD. No difference was found (EBR: t (11) = -.251, p = .806; EBD: t (11) = -1.638, p = .130), therefore baseline 2 was considered superfluous and was not used for further analyses. Due to the lack of a strong division between high and low creativity scores within the data, it was appropriate to use the raw data as a continuous set and use correlational analyses. As EBRs and EBDs were taken at a baseline before experimental conditions were administered as a way to account for individual norm rates and duration, the data from baseline 1 were used as covariates.

2.14 (*see Figure 1. d.*).

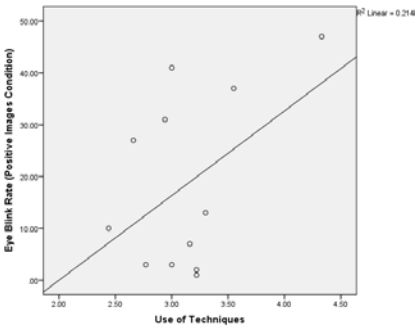

Figure 1. a. Positive relationship between EBR in the positive images condition and 'Use of Techniques' scores.

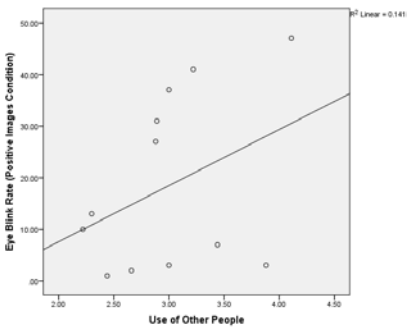

Figure 1. b. Positive relationship between EBR in the positive images condition and 'Use of Other People' scores.

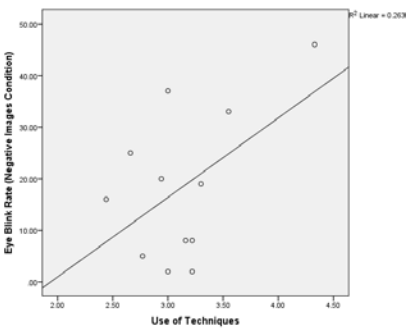

Figure 1. c. Positive relationship between EBR in the negative images condition and 'Use of Technique' scores.

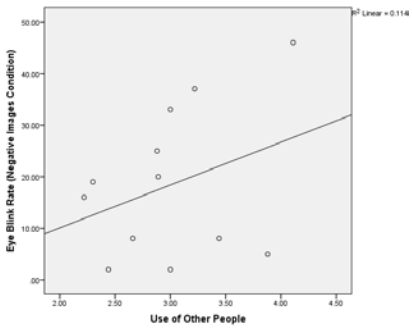

Figure 1. d. Positive relationship between EBR in the negative images condition and 'Use of Other People' scores.

Figure 1. Eye Blink Rate

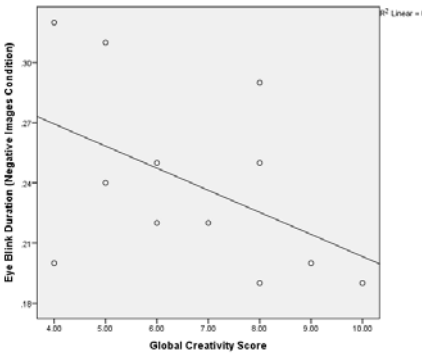

Figure 2. a. Negative correlation between EBD in the negative images condition and Global Creativity scores.

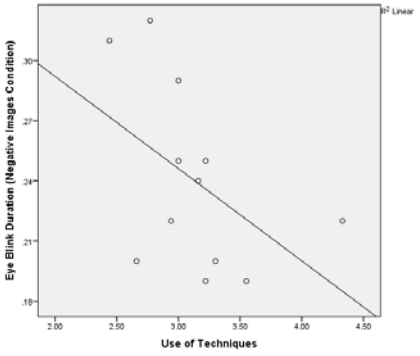

Figure 2. b. Negative relationship between EBD in the negative images condition and 'Use of Techniques' scores.

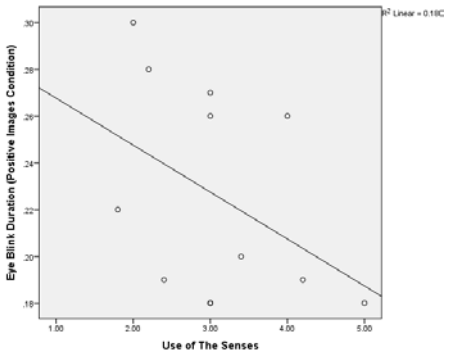

Figure 2. c. Negative relationship between EBD in the positive images condition and 'Use of the Senses' scores.

Figure 2. Eye Blink Duration

Eye Blink Rates

There was no significant difference in EBR between the negative (M = 18.41, SD = 14.48) and positive (M = 18.50, SD = 17.01) image conditions, F (1, 10) = .003, p = .956). Partial correlation analysis (controlling for baseline 1 EBR) revealed no significant relationship between EBR in the positive image condition and global creativity, r (9) = .052, p = .440, or neither in the negative image condition, r (9) = .051, p = .441. A significant positive relationship between the positive image condition EBR and the CSQ-R subcategory 'Use of Techniques' was revealed, r (9) = .563, p = .036, d = 1.36 (see Figure 1. a.), as well as a significant positive correlation between positive images EBR and subcategory 'Use of Other People', r (9) = .731, p = .005, d = 2.14 (see Figure 1. b.). Similarly, a significant positive correlation was found between negative image condition EBR and 'Use of Techniques', r (9) = .668, p = .012, d = 1.74 (see Figure 1. c.), as well as a significant positive correlation between negative image EBR and 'Use of Other People', r (9) = .732, p = .005, d = 2.14 (see Figure 1. d.).

There was no significant difference in EBD between the negative (M = .24, SD = .05) and positive (M = .23, SD = .04) image conditions, F (1, 10) = 2.805, p = .125. Partial correlation analysis (controlling for baseline 1 EBD) revealed no significant relationship between EBD in the positive images condition and global creativity, r (9) = -.393, p = .116. There was, however, a significant negative correlation for EBD in the negative images condition and global creativity, r (9) = -.578, p = .035, d = -1.36 (see Figure 2. a.). A further significant negative correlation was found between negative image condition EBD and 'Use of Techniques', r (9) = -.578, p = 0.031, d = -1.4 (see Figure 2. b.). Finally, a significant negative correlation was revealed between EBD in the positive images condition and 'Use of the Senses', r (9) = -.520, p =.05, d = -1.2 (see Figure 2. c.).

3. Discussion

Following previous evidence that EBR can be used as a marker for dopamine levels, and that highly creative individuals are thought to have higher dopamine activity, the purpose of the current study was to further investigate if EBR could be used to predict different dispositional aspects of creativity. The novel aspect of the work was to also investigate the involvement of serotonin in creativity and the possibility that the chemical activity could be indexed by EBD. It was conducted as a pilot investigation into whether EBD could be used as an additional biological marker. Whilst controlling for individual differences in blink activity, there was no significant relationship found overall between global creativity and EBR. There was also no significant difference in EBR between the negative and positive image conditions. Additionally, no significant difference was found for overall EBD between the image conditions. Interestingly,

however, a significant negative relationship was revealed for EBD and global creativity within the negative image condition, with shorter blink duration correlating with higher global creativity scores, in line with the proposed hypothesis. Analysis further revealed that higher scores in the CSQ-R subcategories 'Use of Techniques' and 'Use of Other People' both correlated significantly, with higher blink rates over both image conditions. It was also found that shorter EBD correlated significantly with higher 'Use of Techniques' scores within the negative image condition. Finally, a significant correlation between shorter EBD and higher scores for the CSQ-R subcategory 'Use of the Senses' was found within the positive images condition. The implications of these findings are discussed below.

The finding that there was no overall relationship found for global creativity and EBR diverges from evidence [53]. Given the amount of evidence which the current finding contradicts, it is difficult to take it at face value without considering basic explanations. The global creativity component consists of only two items, both of which arguably lack sensitivity. For example, 'I am engaged in creative type work on a regular basis' may not necessarily reflect the creative quality of work an individual might produce. The self-rating score of perceived creativity may also be unreliable, as the participants may inaccurately base their view of how generally creative they are. This is a concern when measuring dispositional aspects of behaviour in general and future studies should directly probe creative ability during task performance alongside questionnaire measures (see [57] for discussion of self-report during task vs. dispositional measures of behaviour). Regarding sensitivity of the measure, an analysis of subcomponents of creativity rather than a global measure may be more beneficial when using the CSQ-R. There could also be an element of differences in judgement [58]; a person may judge their own creative production as less extraordinary because it compares similarly to things they have previously produced or does not fall in line with what they consciously consider as 'creative'. However, the finding of a negative correlation between EBD and global creativity scores would oppose the possibility for such flaws in methodology, which will be discussed further. There was no significant difference found for overall EBR or EBD between the image conditions; this deviates from previous research which would allow for the expectation that they would differ between positive and negative mood manipulation [22,41,59]; The images used within the conditions may not have been strong enough manipulation of emotion, which may be reflected in the lack of significant result. As only valence dimension scores for the images were used as a guideline as to how extreme the images were, the rating constraints may not be wide-ranging enough for an effective mood manipulation. As cortical arousal has been linked to creativity [60,61,62], the dimension of arousal may have been better to use either alone or in conjunction with valence. There are more significant findings within the negative image condition than in the positive condition; this could be reflective of increased arousal levels for the negative valence imagery. There has been an association between negative affect and greater autonomic arousal [63]; although the images themselves did not manipulate emotion strongly enough, the negative images may have elicited greater arousal than the positive – the effects of which, according to research (e.g., [60]), may have been more exaggerated in those who are more creative. For EBR, higher blink rates correlated significantly and consistently with higher scores for 'Use of Techniques'. Higher scores in this CSQ-R subcategory were also shown to correlate significantly with shorter EBD within the negative images. Firstly, this consistency for high 'Use of Technique' scores between both EBR and EBD suggests a preliminary evidential basis that EBD could be a reliable measure of creativity. Furthermore, the subcategory 'Use of Techniques' appears to have established itself as a continuous and reliable characteristic or mechanism for creativity. 'Use of Techniques' refers to the extent to which strategies are used to facilitate creativity, such as mind wandering or using previous ideas to create new ones. In view of previous research of EBR being a likely predictor of creativity [53], the results for the current study would suggest that more creative individuals tend to engage in specific creative techniques, as reported by Kumar et al., [52]. This is in concordance with other research which supports the idea that actively engaging in creative techniques and training programmes (e.g., guided creative exercises, such as critical thinking, divergent thinking and problem solving, as well as using motivational or social interactional approaches to support creativity) can be efficacious to producing creative work [64,65,66]. The subcategory 'Use of Other People' revealed itself to be a consistent distinguishing characteristic of creativity within the EBR measure. It makes sense that EBR coincided with higher scores on this subcategory as it would suggest that more highly creative individuals work or consult with other people. This fits in with research showing higher creativity is linked to sociability [67,68] and personality traits such as openness and extraversion [69,70] which also tend to be associated with both sociability [71,72] and creativity [73,74]. As well as 'Use of Techniques', it was revealed that shorter EBD corresponded with higher global creativity scores. This adds support for the hypothesis that EBD can also be used as a marker for creativity. As mentioned above, it is unusual that the same result was not found for EBR. It is, however, noted that the significant correlation was found only within the negative images condition; as abovementioned, this could possibly be due to stronger levels of arousal within the condition than in the positive image condition. The fact that no significant relationship was found for EBR tentatively indicates that EBD may be a more exaggerated marker for emotional arousal than EBR, providing support for the hypotheses from previous literature that serotonin is involved in emotional regulation, particularly in negative affect [75], creativity [39] as well as for the hypothesis of the current study that EBD may be a marker for serotonin activity and creativity. A final discovery that shorter EBD correlated with higher scores of 'Use of the Senses' was found. This subscale measures the extent to which an individual uses the five senses when working creatively. Use of the senses within creativity has been neglected; however, it could be argued that creative production relies heavily on the senses. For instance, a musician would use his eyes to read musical notes, ears to hear them, as well as his hands to play and create a new

piece of music, and a chef may use his sense of smell, taste, and vision to create a new recipe and so on. Support of this result comes from research suggesting that music can engage both hemispheres of the brain [76] and that the so called 'Mozart effect' can facilitate the development of the corpus callosum. This could help cross-talk between the hemispheres, aiding creativity by drawing on multiple sensory areas [40]. A study looking at synaptic integration within taste buds suggests that serotonin is in fact one of the possible neurotransmitters involved in taste cells in some species [77], which could perhaps suggest a link between some senses and serotonin. As 'Use of the Senses' was not shown to correlate significantly with EBR, which has only been demonstrated as a marker for dopamine, support is granted to the notion that EBD is reflecting serotonin levels to some extent. It should be considered that the significant results for EBD within only the negative image condition could be a reflection of EBD reflecting mood state rather than creativity, however it would be likely that more correlations would have been found in this category had this been the case. Additionally, it should be noted that the lack of significant differences in EBR and EBD between image conditions would indicate a lack of significant impact of imagery on these measures. The overall results of this study suggest that EBR can be used as a marker for characteristics of creativity. 'Use of Techniques' and 'Use of Other People' emerged as two convincing and reliable measures for distinguishing mechanisms of creativity, with higher EBR shown to be consistently correlated with high scores in these subcategories, supporting the hypothesis that those with higher EBR can be more creative. It also supports ideas of a connection between EBR and dopamine and the link between dopamine and creativity. This pilot study has also given preliminary evidence of EBD and its viability as an additional marker for creativity. Shorter EBD coincided with higher scores for 'Use of Techniques'; as this subcategory has been demonstrated itself to be a strong measurement for creativity levels in previous studies and within the EBR measure for the current study, it gives good support for the hypothesis that shorter EBD predicts higher creativity. Additional support comes from the fact that EBD negatively correlated with both global creativity and 'Use of the Senses'. As discussed above, these findings give additional evidence that EBD can be used as a predictor of creativity, and additional support to potential links between EBD as a marker for serotonin and serotonin's role in creativity.

A notable area where the study falls short is that although EBD significantly correlated with aspects of creativity, there is an inability for it to fully distinguish whether EBD is a marker for serotonin or if it is actually a secondary reflection of dopamine activity. However, given that there were some inconsistencies in correlations between the EBR and EBD measures, it is reasonable to assume that this is because they are not acting as biological markers for precisely the same thing. One of the study's aims was to give preliminary evidence that EBD could be used as a marker for creativity, which it has achieved. Although there is viable evidence to link this to serotonin activity, it would be unwise to blindly run with the assumption without further insight to the underlying mechanisms which EBD is representing. Regardless, the current study provides the groundwork for subsequent experimental work examine these issues, with recommendation for further investigation into the viability of using EBD as an index of serotonin activity and its relevance to creativity. A broader consideration is that creativity is both difficult to define and measure. However, we argue that studies of this nature using self-report have their place and should be considered alongside experimental studies where creativity is assessed during or after a task. Indeed, it has been suggested that self-reported creativity can be a good measure for identifying creative aptitude [57]. Additionally, divergent thinking tests have positively correlated with self-rated creativity. It should be noted that this study focussed on creativity through creative potential by examining differences in styles and approaches to creativity. The Creativity Styles Questionnaire-Revised has been shown to be reflective of creativity levels, in particular a relationship between use of techniques and creativity level has been seen in studies [52], even when a relationship between trait creativity and divergent thinking performance was absent.

Overall, this pilot study has given further evidence to support the link between dopamine and creativity and that EBR can be a marker for this, however more research is recommended to understand exactly which dopaminergic pathways are responsible for creativity. Although EBD has been shown to be a marker for creativity in a similar way to EBR, more research is needed to fully conclude that the underlying neurotransmitter of EBD activity is in fact serotonin.

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