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DOI:

[10.1177/0269881113512037](https://doi.org/10.1177/0269881113512037)

Document Version

Peer reviewed version

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Citation for published version (APA):

Stokes, P., Benecke, A., Puraite, J., Bloomfield, M. A., Shotbolt, P., Reeves, S., Lingford-Hughes, A. R., Howes, O., & Egerton, A. (2014). Does human presynaptic striatal dopamine function predict social conformity? *Journal of Psychopharmacology*, 28(3), 237-243. <https://doi.org/10.1177/0269881113512037>

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Does human presynaptic striatal dopamine function predict social conformity?

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Abstract word count: 200 Text word count: 3295 Number of Tables: 3

Number of Figures: 1 Supplemental Information: 0

Abstract

Socially desirable responding (SDR), is a personality trait which reflects either a tendency to present oneself in an overly positive manner to others, consistent with social conformity (impression management, IM), or the tendency to view one's own behaviour in an overly positive light (self-deceptive enhancement, SDE). Neurochemical imaging studies report an inverse relationship between SDR and dorsal striatal dopamine $D_{2/3}$ receptor availability. This may reflect an association between SDR and $D_{2/3}$ receptor expression, synaptic dopamine levels or a combination of the two. In this study, we used a [^{18}F]-DOPA positron emission tomography (PET) image database to investigate whether SDR is associated with presynaptic dopamine function. Striatal [^{18}F]-DOPA uptake, (k_i^{cer} , min $^{-1}$), was determined in two independent healthy participant cohorts (n=27 and 19), by Patlak analysis using a cerebellar reference region. SDR was assessed using the revised Eysenck Personality Questionnaire (EPQ-R) Lie scale, and IM and SDE were measured using the Paulhus Deception Scales. No significant associations were detected between Lie, SDE or IM scores and striatal [^{18}F]-DOPA k_i^{cer} . These results indicate that presynaptic striatal dopamine function is not associated with social conformity and suggests that social conformity may be associated with striatal $D_{2/3}$ receptor expression rather than with synaptic dopamine levels.

Key words: [^{18}F]-DOPA, PET, social conformity, personality, dopamine

Introduction

Human neuroimaging studies are providing increasing information about the relationship between brain neurochemistry and personality. In healthy people, variation in striatal dopamine D_{2/3} receptor availability has been associated with personality traits such as neuroticism [Huang *et al.*, 2006], extraversion [Kim *et al.*, 2009], psychoticism [Gray *et al.*, 1994], harm avoidance [Kim *et al.*, 2011], sensation seeking [Gjedde *et al.*, 2010], and novelty seeking [Zald *et al.*, 2008]. As well as providing insights into neurochemical variation which may contribute to interpersonal differences in temperament and identity, these studies may also be relevant in understanding why some individuals are more at risk of psychiatric disorders than others [Soloff *et al.*, 2010, Volkow *et al.*, 2011].

One of the most consistent findings of neurochemical imaging personality studies is an inverse relationship between striatal dopamine D_{2/3} receptor availability and socially desirable responding (SDR), a stable personality construct, which reflects the tendency to present oneself in an overly positive way [Paulhus, 1998]. The negative relationship between SDR and striatal D_{2/3} receptor availability has been observed using the Lie scale of the Maudsley Personality Inventory [Huang *et al.*, 2006], the Lie scale of the Eysenck Personality Questionnaire (EPQ-R) [Reeves *et al.*, 2007, Egerton *et al.*, 2010] and the Swedish universities Scales of Personality [Cervenka *et al.*, 2010]. This relationship is most marked in the dorsal striatum (putamen or sensorimotor functional subdivision) [Reeves *et al.*, 2007, Egerton *et al.*, 2010] and is present

across a wide demographic, being reported in older women [Reeves *et al.*, 2007], and across the adult age range in male and female participants from the United Kingdom [Reeves *et al.*, 2007, Egerton *et al.*, 2010], Taiwan [Huang *et al.*, 2006] and Sweden [Cervenka *et al.*, 2010].

Further analysis of the relationship between individual facets of SDR and striatal D_{2/3} receptor availability, using the Paulhus Deception Scales [Paulhus, 1998], suggests that low receptor availability may principally relate to higher levels of social conformity (presenting a positive impression to others, termed impression management, IM), rather than the tendency to form an overly positive view of one's own personality (termed self-deceptive enhancement, SDE) [Egerton *et al.*, 2010]. This distinction is an important one. If social conformity is viewed as a submissive social behaviour, this is consistent with observations of lower striatal D_{2/3} receptor availability in subordinate compared to socially dominant monkeys [Grant *et al.*, 1998, Shively, 1998, Morgan *et al.*, 2002] and in human participants reporting lower social status or social support [Martinez *et al.*, 2010]. Whilst the relationship is still unclear, this may be of relevance to individual risk of mental health disorders or addiction. For example subordinate monkeys with low striatal D_{2/3} receptor availability have a greater tendency to self-administer cocaine [Morgan *et al.*, 2002], and social defeat has been linked to disorders such as schizophrenia via dopamine dysfunction [Selten *et al.*, 2007].

In the above described neurochemical imaging studies, lower striatal dopamine D_{2/3} receptor availability may reflect either lower expression of striatal D_{2/3} receptors, greater competition with dopamine for receptor binding due to higher extracellular dopamine levels, or a combination of the two [Egerton *et al.*, 2009]. It is therefore unclear whether higher SDR is associated with higher extracellular dopamine levels or lower levels of D_{2/3} receptor expression in the striatum. The relationship between SDR and extracellular dopamine levels or D_{2/3} receptor number has not been directly investigated, and would require PET imaging using a dopamine depletion protocol [Verhoeff *et al.*, 2001, Montgomery *et al.*, 2003]. However, presynaptic striatal dopamine function can be indexed by the simpler procedure of a single 3,4-dihydroxy-6-[¹⁸F]fluoro-L-phenylalanine ([¹⁸F]-DOPA) PET scan. [¹⁸F]-DOPA PET provides a measure of aromatic acid decarboxylase activity (AADC), which converts DOPA to dopamine in presynaptic terminals, and as such the accumulation of [¹⁸F]-DOPA within the brain reflects the functional integrity of presynaptic dopamine synthesis and storage [Cumming *et al.*, 1997] and is inversely correlated with D_{2/3} receptor availability [Ito *et al.*, 2011].

Two previous studies have used [¹⁸F]-DOPA PET to investigate whether SDR is associated with human presynaptic dopamine function. Kaasinen and colleagues found no association in 25 elderly healthy participants and Laakso and colleagues found a non-significant trend level association in the right putamen in 33 healthy adult participants [Kaasinen *et al.*, 2002, Laakso *et al.*, 2003]. Given these inconsistent results and the small number of studies in this area, the aim

of this study was to extend previous findings of an association between SDR and postsynaptic striatal dopamine $D_{2/3}$ receptor availability [Huang *et al.*, 2006, Reeves *et al.*, 2007, Cervenka *et al.*, 2010, Egerton *et al.*, 2010] to investigate whether SDR is related to presynaptic striatal dopamine function in two large independent healthy adult participant cohorts. We hypothesised that SDR would positively correlate with presynaptic sensorimotor striatal dopamine function

Methods

Participants

The first cohort consisted of twenty-seven healthy participants, in whom data was acquired on an ECAT HR+ 962 PET camera as part of ongoing investigations [Egerton *et al.*, 2013]. The second cohort consisted of nineteen healthy participants, in whom data had been acquired on a ECAT/EXACT3D PET camera as part of other studies [Howes *et al.*, 2009, Howes *et al.*, 2011, Shotbolt *et al.*, 2011, Stokes *et al.*, 2013]. All study participants were recruited by public advertisement. In both cohorts, exclusion criteria included history of psychiatric, neurologic or other medical illness, pregnancy or other contraindication to PET imaging, history of head injury and substance dependence with the exception of smoking. All volunteers gave written informed consent for the study, which was approved both by the National Research Ethics service and the Administration of Radioactive Substances Advisory Committee, UK.

Personality assessment

Volunteers completed the full 90-item version of the revised Eysenck Personality Questionnaire (EPQ-R) [Eysenck *et al.*, 1985] and the Paulhus Deception Scales (PDS version 7) [Paulhus, 1998]. In the first cohort, volunteers completed the EPQ-R and PDS questionnaires on the day of PET imaging and in the second cohort volunteers who had previously participated in other studies were re-contacted and asked to complete and return the questionnaires by post. Participants in cohort two completed personality questionnaires an average of 50.7 months after imaging (SD: 21.6 months)

The EPQ-R captures SDR as the Lie scale, and also includes scales of extraversion, neuroticism and psychoticism through scoring categorical yes/no responses to self-descriptive statements [Eysenck *et al.*, 1985]. The PDS measures the tendency to give socially desirable responses on self-report instruments and is divided into two subscales: (i) self-deceptive enhancement (SDE), which measures the tendency to view one's own behaviour in an overly positive light, resulting in honest, but inflated self-descriptions and (ii) impression management (IM), which involves the more conscious use of inflated self-descriptions in presenting oneself favourably to an audience. PDS items are presented as 40 statements and respondents are asked to indicate the degree to which each statement applies to them on a 5-point scale ranging from 'Not True' to 'Very True.' The SDE scale is scored dichotomously, assigning points only for the most extreme responses to ensure only extreme claims of overconfidence

are assessed. The IM scale is scored continuously. As stated in the PDS manual [Paulhus, 1998], individuals with IM scores of > 8 indicate potential dissimulation ('faking good'), rather than 'true' individual differences in social conformity. As dissimulation may invalidate other self-report measures, and confound investigation of the relationship between dopamine function and social conformity [Egerton *et al.*, 2010], data are presented before and after exclusion of individuals with IM scores > 8 .

[^{18}F]-DOPA PET procedures

All participants were asked to fast and abstain from alcohol, cigarettes or other substance use for 12 hours prior to imaging. Each volunteer underwent a urine drug screen analysis on the day of the scan and were excluded if it was positive for cannabis, cocaine, methamphetamine, amphetamine, opiates and benzodiazepines. All volunteers received 150mg carbidopa and 400mg entacapone orally one hour before scanning to reduce the formation of radiolabeled metabolites [Wahl *et al.*, 1994]. On positioning in the PET scanner, head position was marked and monitored via laser crosshairs and a camera, and minimized using a light head-strap.

In the first cohort, PET data was acquired on an ECAT HR+ 962 PET scanner (CTI/Siemens) in 3D mode. A 10-minute transmission scan was performed prior to radiotracer injection to correct for attenuation and scatter. A mean of 181.3 (SD: 4.7) MBq of [^{18}F]-DOPA was administered by bolus intravenous injection 30

seconds after the start of the PET imaging. Emission data were acquired in list mode for 95 minutes, rebinned into 26 time-frames. In the second cohort, PET data was acquired using the ECAT/EXACT3D 966 PET scanner (CTI/Siemens/CTI) in 3D mode. A mean of 149.7 (SD: 6.1) MBq of [^{18}F]-DOPA was administered by bolus intravenous injection 30 seconds after the start of the PET imaging. Emission data were acquired in list mode over 95 minutes, rebinned into 26 time-frames. In house phantom data show that both these scanners are similar in terms of spatial resolution (full width half maximum, ECAT 966: 5.3mm ECAT 962: 5.1mm) but that the ECAT 962 tomograph has less intrinsic sensitivity than the ECAT 966 (T Spinks, personal communication).

Image analysis

All scans were first corrected for head movement using frame by frame realignment as previously described [Montgomery *et al.*, 2006]. A region of interest (ROI) analysis was performed using an atlas comprised of the three functional subdivisions of the striatum; limbic, associative and sensorimotor striatum along with the cerebellum. These functional striatal subdivisions are anatomically analogous to the ventral striatum (limbic striatum), precommissural dorsal putamen, precommissural dorsal caudate and post commissural dorsal caudate (associative striatum) and post-commissural putamen (sensorimotor striatum) [Martinez *et al.*, 2003]. Right and left hemispheric areas of each striatal subdivision were combined and sampled together. An [^{18}F]-DOPA template

[Howes *et al.*, 2009] was spatially transformed to the individual PET space of each movement corrected PET summation image using statistical parametric mapping (SPM5; Wellcome Department of Cognitive Neurology, London, England) and the resulting deformation matrix was then applied to the atlas [Meyer *et al.*, 1999]. This procedure allows for ROI's to be placed automatically on individual [^{18}F]-DOPA PET images without observer bias. [^{18}F]-DOPA utilization, relative to the cerebellar reference tissue (k_i^{cer} (min $^{-1}$) alternatively designated as K_i), was calculated for each ROI using graphical analysis, adapted for a reference tissue input function [Cumming *et al.*, 1997, Cumming *et al.*, 1997, Egerton *et al.*, 2010]. Previous test-retest data show that this approach generates sensorimotor striatal k_i^{cer} values with good reproducibility (percentage test-retest variability: $5.89\% \pm 4.82$) and reliability (intraclass correlation coefficient = 0.68) [Egerton *et al.*, 2010].

Statistical analysis

Statistical analysis was performed using SPSS version 19.0 (SPSS, Chicago, USA). Data were checked for normality of distribution using one-sample Komlogorov-Smirnov tests. Relationships between scores on parametrically distributed individual personality scores and regional k_i^{cer} values were explored using partial Pearson's correlations correcting for age and gender which have both previously been shown to affect [^{18}F]-DOPA k_i^{cer} values [Laakso *et al.*, 2002]. Relationships between scores on non-parametrically distributed individual

personality scores and regional k_i^{cer} values were explored using partial Spearman's correlations correcting for age and gender.

As data in the two cohorts were acquired on different PET scanners with differing sensitivity parameters, each cohort was analyzed separately. Our *a priori* hypothesis concerned the relationship between sensorimotor striatal [^{18}F]-DOPA k_i^{cer} and scores on the Lie and IM scales after exclusion of potential dissimulators (those with IM scores > 8). These correlations were explored at $p=0.05$ uncorrected in each participant cohort separately. Exploratory analyses of relationships between [^{18}F]-DOPA k_i^{cer} in other areas of the striatum and personality variables (extroversion, psychoticism, neuroticism, SDE) were Bonferroni corrected for twelve multiple comparisons ($p<0.004$, 4 personality scales x 3 anatomical regions). Power analyses were conducted using G*Power 3.1 [Faul *et al.*, 2009].

Results

Personality scores and presynaptic dopamine function across the two cohorts

	Cohort 1 (n=27)	Cohort 2 (n=19)	P value
Age (years)	25.2 (6.1)	38.0 (14.0)	0.001
Gender	18M/9F	10M/9F	0.32
Cigarette smoking status	6 current smokers/ 21 non-smokers	2 current smokers/ 17 non-smokers	0.28
EPQ-Lie score	8.1 (3.5)	9.4 (4.3)	0.27
PDQ-IM score	6.6 (4.0)	8.5 (3.6)	0.10
PDQ-SDE score	2.5 (1.9)	2.4 (2.0)	0.87
EPQ-N score	6.3 (4.1)	13.5 (4.4)	< 0.001
EPQ-P score	2.8 (2.0)	8.1 (5.5)	< 0.001
EPQ-E score	15.5 (3.8)	3.9 (2.6)	< 0.001
Limbic striatal k_i^{cer}	0.0136 (0.0012)	0.0149 (0.0009)	< 0.001
Associative striatal k_i^{cer}	0.0125 (0.0009)	0.0144 (0.0011)	< 0.001
Sensorimotor striatal k_i^{cer}	0.0133 (0.0101)	0.0159 (0.0013)	< 0.001
Overall striatal k_i^{cer}	0.0131 (0.0010)	0.0149 (0.0010)	< 0.001

Table 1: Participant demographics, mean personality scores and [^{18}F]DOPA k_i^{cer} values for each participant cohort ($\pm$ SD)

Participant demographics, personality scores and [^{18}F]-DOPA k_i^{cer} values are presented in Table 1. In both cohorts, scores on all personality scales were normally distributed (one-sample Komlogorov-Smirnov test $p > 0.05$) except for EPQ-N scores (Komlogorov-Smirnov test cohort one $p = 0.03$ and cohort two

$p=0.002$). There was no significant difference in scores on the social desirability scales (Lie, SDE or IM) across the two cohorts (all p values >0.05), however in the first cohort EPQ-N and EPQ-P scores were significantly lower (p values <0.001) and EPQ-E scores were significantly higher ($p<0.001$). There was no significant correlation between age and scores on Lie, SDR or IM scales in either cohort (all $p > 0.05$). While there was no effect of gender on Lie, SDE or IM score in the first cohort, in the second cohort women had significantly higher Lie and IM scores than men (mean male and female Lie scores (SD): 7.6 (4.0), 11.4 (3.9); $p=0.05$; mean male and female IM scores (SD): 5.9 (2.5); 11.4 (2.0); $p<0.001$). Eight of the 27 participants (30%, 3 males) in the first cohort and eleven of the 19 participants (58%, 2 males) in the second cohort had IM scores > 8 , indicating potential dissimulation.

Data from the two cohorts were acquired on different PET scanners and all [^{18}F]-DOPA k_i^{cer} values were significantly higher in the second cohort (all p values < 0.001). Due to the significant differences in k_i^{cer} , the cohorts were not combined to explore relationships between presynaptic dopamine function and personality.

Relationships between Lie and IM scores and presynaptic striatal dopamine function

	Limbic striatum		Associative striatum		Sensorimot or striatum		Overall striatum			Limbic striatum		Associative striatum		Sensorimot or striatum		Overall striatum	
	r	p	r	p	r	p	r	p		r	p	r	p	r	p	r	p
Cohort 1 personality scores excluding dissimulators (n=19)									Cohort 2 personality scores excluding dissimulators (n=8)								
EPQ-L	-0.04	0.89	-0.17	0.50	-0.15	0.56	-0.19	0.47	0.03	0.95	-0.36	0.43	-0.43	0.32	-0.39	0.39	
IM	0.04	0.88	-0.13	0.60	-0.19	0.47	-0.13	0.62	0.22	0.62	0.18	0.70	-0.22	0.63	0.08	0.86	
Cohort 1 personality scores including dissimulators (n=27)									Cohort 2 personality scores including dissimulators (n=19)								
EPQ-L	0.18	0.40	0.12	0.56	0.08	0.69	0.11	0.61	-0.17	0.51	-0.11	0.67	-0.14	0.59	-0.14	0.58	
IM	0.36	0.07	0.11	0.61	-0.01	0.97	0.12	0.58	-0.40	0.11	-0.05	0.84	-0.32	0.20	-0.18	0.48	

Table 2: Correlation coefficients between Lie and IM scores and striatal [^{18}F]DOPA k_i^{cer} (r= partial Pearson's correlations correcting for age and gender, p=statistical significance of correlation)

Figure 1: Lack of significant relationship between Lie scores and presynaptic dopamine function ([^{18}F]-DOPA k_i^{cer} , min $^{-1}$) in the sensorimotor striatum in each of the two cohorts of healthy volunteers. The data is presented after exclusion of potential dissimulators.

Table 2 presents the correlation coefficients between Lie and IM scores and striatal [^{18}F]-DOPA k_i^{cer} values. There were no significant correlations between

Lie or IM scores and [^{18}F]-DOPA k_i^{cer} values in the sensorimotor striatum after exclusion of potential dissimulators (see Figure 1 for Lie scores). The pattern of these findings did not change with the inclusion of potential dissimulators (p value>0.05). There were also no significant correlations between Lie or IM scores and [^{18}F]-DOPA k_i^{cer} values in either the limbic or associative striatum, or in the striatum as a whole irrespective of whether potential dissimulators were excluded from the analysis (all p values>0.05).

Relationships between other personality variables and presynaptic striatal dopamine function

	Limbic striatum		Associative striatum		Sensorimotor or Striatum		Overall Striatum	
	r	p	r	p	r	p	r	p
Cohort 1 personality scores excluding dissimulators (n=19)								
SDE	0.24	0.36	0.04	0.88	-0.13	0.61	0.05	0.86
EPQ-N	0.22	0.86	0.49	0.67	0.56	0.61	0.56	0.61
EPQ-P	0.11	0.68	0.10	0.68	0.27	0.30	0.16	0.54
EPQ-E	-0.19	0.47	-0.24	0.35	-0.03	0.89	-0.21	0.43
Cohort 1 personality scores including dissimulators (n=27)								
SDE	-0.01	0.99	-0.07	0.75	-0.14	0.50	0.01	0.96
EPQ-N	0.04	0.97	0.34	0.78	0.55	0.63	0.39	0.74
EPQ-P	0.14	0.49	0.12	0.58	0.24	0.24	0.23	0.28
EPQ-E	-0.02	0.93	-0.06	0.77	0.10	0.62	-0.05	0.80
	Limbic striatum		Associative striatum		Sensorimotor striatum		Overall striatum	
	r	p	r	p	r	p	r	p
Cohort 2 personality scores excluding dissimulators (n=8)								
SDE	0.16	0.73	0.34	0.45	0.82	0.02	0.49	0.26
EPQ-N	0.61	0.58	0.05	0.96	-0.17	0.89	-0.09	0.94
EPQ-P	0.38	0.40	0.47	0.29	-0.12	0.80	0.33	0.46
EPQ-E	0.60	0.15	0.53	0.22	0.87	0.01	0.67	0.10
Cohort 2 personality scores including dissimulators (n=19)								
SDE	0.45	0.07	0.23	0.36	0.45	0.07	0.36	0.15
EPQ-N	0.75	0.46	0.71	0.50	0.82	0.39	0.75	0.46
EPQ-P	0.43	0.09	0.30	0.25	-0.03	0.92	0.23	0.36
EPQ-E	0.41	0.10	0.36	0.15	0.73	0.001	0.52	0.03

Table 3: Correlation coefficients between SDE, EPQ-N, EPQ-P and EPQ-E scores and striatal [^{18}F]-DOPA k_i^{cer} (r=partial Pearson's correlations correcting for age and gender (partial Spearman's correlations correcting for age and gender for EPQ-N scores).
p=statistical significance of correlation)

Exploratory analysis of the remaining personality variables and k_i^{cer} values across striatal subdivisions found a positive correlation in the second participant cohort between SDE and sensorimotor striatal k_i^{cer} values after excluding potential dissimulators (r=0.82; p=0.02). However this relationship did not survive

correction for multiple comparisons and was not apparent in the first cohort ($r=-0.13$; $p=0.61$) after excluding potential dissimulators. No further relationships between SDE and either limbic or associative striatal k_i^{cer} values were apparent either before or after exclusion of potential dissimulators (all p values >0.05).

A significant positive correlation, which survived correction for multiple comparisons, was found in the second cohort between extraversion scores and sensorimotor striatal k_i^{cer} values ($r=0.73$, $p=0.001$). This relationship was not significant in the first cohort ($r=0.10$, $p=0.62$) and did not survive multiple comparison correction in the second cohort after exclusion of potential dissimulators ($r=0.87$, $p=0.01$). We found no relationship between neuroticism or psychoticism scores and k_i^{cer} values in the overall striatum or any functional striatal subdivision either before or after exclusion of potential dissimulators (all p values >0.05).

Discussion

This study found no association between socially desirable responding and presynaptic striatal dopamine function in two independent participant cohorts, irrespective of whether potential dissimulators were excluded from the analysis. These results are consistent with those of Kaasinen and colleagues who found no association between [^{18}F]-DOPA k_i^{cer} values and KSP social desirability scores in elderly healthy participants [Kaasinen *et al.*, 2002]. They are also consistent with those of Laakso and colleagues who reported a non-significant trend level association ($n=33$, $r=0.36$, $p=0.07$) between social desirability, as measured on the Karolinska Scales of Personality, and [^{18}F]-DOPA uptake in the right putamen [Laakso *et al.*, 2003]. Neither of these studies examined the effect of potential dissimulation as a confounding factor.

The lack of relationship between presynaptic striatal dopamine function and SDR is in contrast with studies of postsynaptic striatal dopamine $\text{D}_{2/3}$ receptor availability where a negative relationship with SDR has been consistently reported [Huang *et al.*, 2006, Reeves *et al.*, 2007, Cervenka *et al.*, 2010, Egerton *et al.*, 2010]. Assuming that presynaptic dopamine function is positively correlated with synaptic dopamine concentration [Ito *et al.*, 2011], one interpretation of these findings is that social conformity is associated with individual differences in postsynaptic dopamine $\text{D}_{2/3}$ receptor availability rather

than synaptic dopamine levels. We would suggest that dopamine depletion studies are required to further test this hypothesis.

The idea that social conformity may be linked to postsynaptic D_{2/3} receptor availability rather than presynaptic dopamine function is an interesting one. For example, dopamine dysfunction in schizophrenia, and risk of psychosis, has been most consistently associated with abnormalities of presynaptic dopamine function, with little change in postsynaptic D_{2/3} receptor availability, indicating that the primary risk factors may impact upstream of the striatal dopamine synapse [Howes *et al.*, 2009, Howes *et al.*, 2012, Fusar-Poli *et al.*, 2013]. In contrast, many addictive disorders, and possibly vulnerability to addiction, have been associated with low striatal D_{2/3} receptor availability [Volkow *et al.*, 2009]. The current research suggests that, like addiction, social conformity may be associated with postsynaptic dopaminergic regulation. Further work is required, but these studies begin to contribute to a biosocial model whereby personality and environment may interact with different aspects of the striatal dopaminergic synapse to affect predisposition towards psychiatric disorders or addiction.

Additional exploratory analyses found a significant positive correlation, which survived multiple comparison correction, between extraversion scores in cohort two and presynaptic sensorimotor striatal dopamine function. However this relationship was not replicated in the first cohort and did not survive multiple comparison correction in the second cohort after exclusion of potential

dissimulators. The results from the second cohort are also not consistent with a previous [^{18}F]-DOPA study of extraversion which found no association with striatal uptake [Laakso *et al.*, 2003].

There are several limitations to this present study. Firstly, it is possible that both participant cohorts were underpowered to detect a significant association between SDR and presynaptic dopamine function. However power analysis suggested that this study was adequately powered (cohort one: power = 0.86; cohort two: power = 0.77) to detect a correlation between SDR and presynaptic dopamine function at $P < 0.05$ and the sample sizes are similar to those in which significant relationships between SDR and $\text{D}_{2/3}$ receptor availability have previously been reported [Huang *et al.*, 2006, Reeves *et al.*, 2007, Cervenka *et al.*, 2010, Egerton *et al.*, 2010]. Secondly, participants in the second cohort completed personality questionnaires an average of around 51 months after imaging which raises the possibility that Lie scores may have changed significantly over this time period. However, the stability of Lie scores is quite high even over a 6-8 year period (Cronbach alpha: 0.72) which makes this unlikely [Loehlin *et al.*, 2001]. Finally, as [^{18}F]-DOPA PET measures AADC enzyme activity, it does not provide a direct measure of synaptic dopamine levels or release but rather a measure of presynaptic dopamine synthesis capacity. Ito and colleagues found correlations between overall striatal [^{18}F]-DOPA uptake and striatal $\text{D}_{2/3}$ receptor availability but were not able to demonstrate this association in the caudate or putamen [Ito *et al.*, 2011]. It is therefore possible

that we may not have found an association between SDR and [^{18}F]-DOPA uptake due to the variability in correlations between [^{18}F]-DOPA uptake and synaptic dopamine levels.

In summary, unlike studies of postsynaptic striatal $\text{D}_{2/3}$ dopamine receptor availability, we did not find evidence that presynaptic dopamine function is associated with socially desirable responding in man. In the context of previous literature, these findings suggest that socially desirable responding may be associated with the postsynaptic expression of the striatal dopamine $\text{D}_{2/3}$ receptor rather than with synaptic striatal dopamine levels.

Acknowledgments

This study was funded by grant funding (grant codes: U.1200.04.007.00001.01 and MC-A656-5QD30) from the Medical Research Council, UK.

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