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Does human presynaptic striatal dopamine function predict social conformity?

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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, ($k^{\text{cer}}$, 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 $k^{\text{cer}}$. 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
D23 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
D23 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
D23 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<sub>2/3</sub> receptor availability may reflect either lower expression of striatal D<sub>2/3</sub> 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<sub>2/3</sub> receptor expression in the striatum. The relationship between SDR and extracellular dopamine levels or D<sub>2/3</sub> 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 ([<sup>18</sup>F]-DOPA) PET scan. [<sup>18</sup>F]-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 [<sup>18</sup>F]-DOPA within the brain reflects the functional integrity of presynaptic dopamine synthesis and storage [Cumming et al., 1997] and is inversely correlated with D<sub>2/3</sub> receptor availability [Ito et al., 2011].

Two previous studies have used [<sup>18</sup>F]-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.

[^18F]-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[^18F]-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 [18F]-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 comissural dorsal caudate (associative striatum) and post-comissural putamen (sensorimotor striatum) [Martinez et al., 2003]. Right and left hemispheric areas of each striatal subdivision were combined and sampled together. An [18F]-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 [18F]-DOPA PET images without observer bias. [18F]-DOPA utilization, relative to the cerebellar reference tissue ($k_{c}^{cer}$ (min-1) alternatively designated as Ki), 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 $k_{c}^{cer}$ values with good reproducibility (percentage test-retest variability: 5.89% ± 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 $k_{c}^{cer}$ values were explored using partial Pearson’s correlations correcting for age and gender which have both previously been shown to affect [18F]-DOPA $k_{c}^{cer}$ values [Laakso et al., 2002]. Relationships between scores on non-parametrically distributed individual
personality scores and regional $k^{\text{cer}}$ 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 $[^{18}\text{F}]-\text{DOPA}$ $k^{\text{cer}}$ 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 $[^{18}\text{F}]-\text{DOPA}$ $k^{\text{cer}}$ 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 $\times$ 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**

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

Table 1: Participant demographics, mean personality scores and $[^{18}F]$DOPA $k^{icer}$ values for each participant cohort (±SD)

Participant demographics, personality scores and $[^{18}F]$-DOPA $k^{icer}$ 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
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 $[^{18}\text{F}]-\text{DOPA} \ k^\text{cer}$ values were significantly higher in the second cohort (all p values<0.001). Due to the significant differences in $k^\text{cer}$, 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

Figure 1: Lack of significant relationship between Lie scores and presynaptic dopamine function ([18F]-DOPA $k^{icre}$, 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 [18F]-DOPA $k^{icre}$ values. There were no significant correlations between
Lie or IM scores and $[^{18}\text{F}]-\text{DOPA } k^{\text{cer}}$ 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 $[^{18}\text{F}]-\text{DOPA } k^{\text{cer}}$ 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*

![Table](image)

<table>
<thead>
<tr>
<th>Cohort 1 personality scores excluding dissimulators (n=19)</th>
<th>Cohort 2 personality scores excluding dissimulators (n=19)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SDE</strong></td>
<td>0.74</td>
</tr>
<tr>
<td><strong>EPQ-N</strong></td>
<td>0.32</td>
</tr>
<tr>
<td><strong>EPQ-P</strong></td>
<td>0.11</td>
</tr>
<tr>
<td><strong>EPQ-E</strong></td>
<td>0.12</td>
</tr>
</tbody>
</table>

Exploratory analysis of the remaining personality variables and $k^{\text{cer}}$ values across striatal subdivisions found a positive correlation in the second participant cohort between SDE and sensorimotor striatal $k^{\text{cer}}$ 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 $k_{cr}$ 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 $k_{cr}$ 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 $k_{cr}$ 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 $[^{18}\text{F}]-\text{DOPA}\; k_{\text{cer}}$ 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 $[^{18}\text{F}]-\text{DOPA}$ 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 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 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 $D_2/3$ 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 $D_2/3$ 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 $[^{18}\text{F}]-\text{DOPA}$ uptake due to the variability in correlations between $[^{18}\text{F}]-\text{DOPA}$ uptake and synaptic dopamine levels.

In summary, unlike studies of postsynaptic striatal $D_{2/3}$ 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 $D_{2/3}$ receptor rather than with synaptic striatal dopamine levels.

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