Personality and Individual Differences 78 (2015) 24–28

Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid

Gray's revised Reinforcement Sensitivity Theory in relation to Attention-Deficit/Hyperactivity and Tourette-like behaviors in the general population

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ARTICLE INFO

Article history:
Received 2 September 2014
Received in revised form 29 December 2014
Accepted 13 January 2015
Available online 2 February 2015

Keywords:
ADHD
Tourette syndrome
Reinforcement sensitivity
BIS/BAS

ABSTRACT

Attention-Deficit/Hyperactivity Disorder (ADHD) and Tourette syndrome (TS) present as distinct conditions clinically; however, they show comorbidity and inhibitory control deficits have been proposed to underlie both. The role of reinforcement sensitivity in ADHD has been studied previously, but no study has addressed this in relation to TS-like behaviors in the general population. The present study examined these associations within the remit of the revised Reinforcement Sensitivity Theory (rRST). One hundred and thirty-eight participants completed psychometric measures of the rRST, and self-report checklists for ADHD- and TS-like behaviors. The results show that whilst ADHD-inattention was only linked to increased anxiety (BIS), ADHD-hyperactivity/impulsivity was linked to increased impulsivity (BAS-fun seeking), anxiety (BIS) and punishment sensitivity (FFFS), and to reduced reward sensitivity (BAS-reward responsiveness), independently of 'comorbid' TS-like behaviors. TS-related phonic tics were associated with increased BIS and FFFS, and TS-related obsessive–compulsive behaviors (OCBs) with increased goal-orientation (BAS-drive) and reduced impulsivity (BAS-fun seeking). However, these associations were driven by ADHD-like behaviors or OCB co-occurrence, respectively, suggesting little role of the rRST in pure TS-like behaviors. The results are discussed in light of mixed findings in the literature and the importance of distinguishing between multiple processing models of the rRST in distinct disorder phenotypes.

1. Introduction

It has been suggested that the symptoms of Attention-Deficit/Hyperactivity Disorder (ADHD) derive from a primary executive inhibitory control deficit (Barkley, 1997) though motivational inhibitory deficits have also been proposed (e.g., Newman & Wallace, 1993; Nigg, 2000; Quay, 1997). There is a high comorbidity of ADHD in Tourette syndrome (TS) whereby up to 80% of TS patients also exhibit symptoms of ADHD, and these appear to precede the emergence of TS associated tics (Cavanna & Rickards, 2013). Similar to ADHD, it is argued that TS is the result of an inhibitory dysfunction (Sheppard, Bradshaw, Purcell, & Pantelis, 1999), though the overall evidence is inconsistent, possibly due to varying levels of comorbidity with ADHD (Pennington & Ozonoff, 1996). Indeed, pure TS may rather be characterized by enhanced executive control (Jackson, Mueller, Hambleton, & Hollis, 2007; Jung, Jackson, Nam, Hollis, & Jackson, 2014) and there is no evidence for automatic inhibitory deficits in TS patients without comorbidity (Ozonoff, Strayer, McMahon, & Filloux, 1998; Yuen, Bradshaw, Sheppard, Lee, & Georgiou-Karistianis, 2005) and independent of medication effects (Kantini, Cassaday, Hollis, & Jackson, 2011). Similar findings were recently shown in relation to TS-like behaviors in the general population when ADHD was controlled for (Heym, Kantini, Checkley, & Cassaday, 2014). These findings suggest that TS does not occur in conjunction with deficits in effortful or automatic associative response inhibition. Recently, the application of reinforcement learning models has been proposed to further our understanding of the processes involved in complex symptom patterns in psychiatric and neurological disorders (Bijttebier, Beck, Claes, & Vandereycken, 2009; Maia & Frank, 2011). Although primarily a motor-disorder, the involvement of fronto-striatal dopaminergic pathways and basal ganglia circuitry in the etiology of TS (Robertson, 2000) and the central role of these pathways in reinforcement learning suggests a role for

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http://dx.doi.org/10.1016/j.paid.2015.01.012
0191-8869/

reinforcement sensitivity and motivational inhibitory processes in this disorder (Maia & Frank, 2011 for review).

1.1. Reinforcement Sensitivity Theory (RST)

Gray's (1982) original model proposed three neuropsychological systems underpinning approach-avoidance motivation and behavior – the functioning of which was related to personality. Recent revisions to the theory (rRST; Gray & McNaughton, 2000) led to some changes in the conceptualization of the systems involved (Pickering & Corr, 2008). In the rRST, the behavioral approach system (BAS) is a reward-sensitive system – activation leads to goal-oriented approach behavior. BAS is linked to trait impulsivity. The Fight-Flight-Freeze System (FFFS) is a punishment-sensitive system – activation leads to active avoidance behavior, and it is the causal basis of fear. The behavioral inhibition system (BIS) responds to conflicting (aversive and/or appetitive) cues leading to inhibition of the ongoing response, risk assessment and appraisal. BIS is linked to trait anxiety and worry. The main changes in the revision are that punishment sensitivity, originally ascribed to BIS, is now defined by the FFFS, whereas BIS is responsible for resolving goal conflicts. Dysfunctions in these systems have been proposed to lead to various clinical outcomes; for instance, overactivity of the checking mode of the BIS relates to symptoms of obsessive compulsive disorder (OCD), general anxiety and related internalizing disorders, whereas overactivity of BAS relates to externalizing disorders (Gray, 1982; Gray & McNaughton, 2000).

1.2. Reinforcement sensitivity in ADHD and TS

ADHD is an externalizing disorder, and as such, an overactive BAS leading to response modulation deficits has been proposed to underlie ADHD (Newman & Wallace, 1993). Alternative models have proposed an underactive BIS (Quay, 1988), or an interaction between high levels of BAS relative to low levels of BIS, to be responsible for the inhibition deficits seen in ADHD (Quay, 1997). Experimental studies support the notion of dysfunctional reward processing in ADHD (Luman, Oosterlaan, & Sergeant, 2005; Paloyelis, Asherson, & Kuntsi, 2009), though taken together, the findings for the effectiveness of reinforcing contingencies in reducing the primary response inhibition deficits in ADHD are mixed (Oosterlaan & Sergeant, 1998). Dual pathway models of ADHD assume however, that (i) deficits in executive or cognitive control underlie inattention symptoms, whereas (ii) deficits in motivational control and reward sensitivity underlie hyperactivity/impulsivity symptoms (Martel & Nigg, 2006). A recent meta-analysis of general personality associations with ADHD suggests executive and motivational deficits in both symptom groups, though inattention was more strongly linked to executive and hyperactivity/impulsivity more strongly to motivational traits (Gomez & Corr, 2014). With regards to the RST, ADHD-inattention has been linked to increased levels of BIS (Gomez & Corr, 2010; Hundt, Kimbrel, Mitchell, & Nelson-Gray, 2008; Mitchell & Nelson-Gray, 2006), whereas hyperactivity/impulsivity has been mainly associated with increased BAS (Gomez & Corr, 2010), though also with reduced (Hundt et al., 2008) or increased BIS (Mitchell & Nelson-Gray, 2006) in non-clinical samples. These findings are consistent with overactive BAS, but inconsistent regarding the role of an underactive BIS in ADHD. Importantly, the main propositions of the BIS/BAS models for ADHD and the majority of research findings (apart from Gomez & Corr, 2010) have been within the remit of the original RST – as such conflating behavioral inhibition (BIS) with punishment sensitivity (FFFS).

Despite the high comorbidity of ADHD and TS, little is known about the underlying commonalities and differentiations in reinforcement sensitivity of these two disorders. Studies have found (i) greater amygdala activation for fearful, angry and neutral facial expressions in TS patients (though comorbidity was not controlled; Neuner et al., 2010); (ii) impaired punishment learning in unmedicated TS patients, whereas reward sensitivity and reward learning were only reduced in medicated and OCD-comorbid TS patients (Palminteri et al., 2009, 2011; Worbe et al., 2011); and (iii) no differences in reward learning between pure TS patients and healthy controls (Crawford, Channon, & Robertson, 2005). These findings suggest increased sensitivity to aversive and ambiguous cues (overactive FFFS and BIS) but deficits in negative reinforcement learning (dysfunctional FFFS or BIS) in TS, whereas reward processing deficits (underactive BAS) appear to be linked to medication status and presence of OCD symptoms. These findings may be due to impairment of distinct cortico-striatal circuits involved in different phenotypes of TS with varying symptom complexity or comorbidities (Worbe et al., 2010), resulting in different patterns of reinforcement sensitivity deficits.

Whilst researchers have begun to examine the associations of the phenotypes of ADHD in relation to rRST in the general population (Gomez & Corr, 2010), to our knowledge, this approach has not been extended to the examination of TS-like behaviors. Therefore, the aim of the current study was to examine individual differences in reinforcement sensitivity in the different phenotypic expressions of both ADHD- and TS-like behaviors in the general population. In order to tease apart the roles of the rRST constructs, we assess their unique associations with both overall and distinct phenotypical behaviors accounting for sex, age and 'comorbidity' with each other (Gomez & Corr, 2010). In line with Gomez and Corr (2010), we predicted that BAS-fun seeking would be related to increased hyperactivity/impulsivity whereas BIS-anxiety should relate to increased inattention ADHD-like behaviors. Given the previous findings in clinical TS (e.g., Palminteri et al., 2009, 2011), we expected a dysfunctional BIS and/or FFFS to be linked to pure phonic and motor TS-like behaviors and any associations with BAS to be due to 'comorbidity' in TS-like behaviors.

2. Method

2.1. Participants and procedure

The sample consisted of 138 undergraduate participants (90 females and 48 males; mean age = 23.54; SD = 4.62; 17–40 years). The study was approved by the School of Psychology Research Ethics Committee of the University of Nottingham, and the R&D Departments of the Nottinghamshire Lincolnshire Partnership NHS Trust (Derbyshire REC, ref 08/H0401/34, approved April 2008). Written consent was acquired from all participants (or written consent from parents and verbal assent from minor participants) prior to participation.

2.2. Measures

Reinforcement sensitivity was assessed using the BIS/BAS scales (Carver & White, 1994) consisting of: BIS-original (7 items), BAS-drive (4 items), BAS-fun seeking (4 items), and BAS-reward responsiveness (5 items). Following rRST (Heym, Ferguson, and Lawrence (2008), the BIS scale was split into BIS-anxiety (4 items) and FFFS-fear (3 items). Items were scored on a 4-point scale (1 = very true to 4 = very false for me), reversed scored such that higher scores indicate higher endorsement of respective RST constructs, and mean scores were calculated. Previous alphas ranged from .57 to .76 (Heym et al., 2008). In the current study the alphas (and mean inter-item correlations for scales < 5 items) were acceptable ranging from .72 (MIC = .40) for BIS-anxiety to .82 (MIC = .54) for