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Perceptual, cognitive, and personality rigidity in Parkinson's disease

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ABSTRACT

Parkinson's disease (PD) is associated with motor and non-motor rigidity symptoms (e.g., cognitive and personality). The question is raised as to whether rigidity in PD also extends to perception, and if so, whether perceptual, cognitive, and personality rigidities are correlated. Bistable stimuli were presented to 28 non-demented individuals with PD and 26 normal control adults (NC). Necker cube perception and binocular rivalry were examined during passive viewing, and the Necker cube was additionally used for two volitional-control conditions: *Hold* one percept in front, and *Switch* between the two percepts. Relative to passive viewing, PD were significantly less able than NC to reduce dominance durations in the *Switch* condition, indicating perceptual rigidity. Tests of cognitive flexibility and a personality questionnaire were administered to explore the association with perceptual rigidity. Cognitive flexibility was not correlated with perceptual rigidity for either group. Personality (novelty seeking) correlated with dominance durations on Necker passive viewing for PD but not NC. The results indicate the presence in mild-moderate PD of perceptual rigidity and suggest shared neural substrates with novelty seeking, but functional divergence from those supporting cognitive flexibility. The possibility is raised that perceptual rigidity may be a harbinger of cognitive inflexibility later in the disease course.

1. Introduction

Parkinson's disease (PD) has primarily been conceptualized as a movement disorder, as it is characterized by tremor, motor rigidity (e.g., axial rigidity, decreased arm swing and stride length, lack of spontaneous eye movement), bradykinesia, and postural instability. As an example of the increasing emphasis on non-motor as well as motor symptoms (reviewed in Cronin-Golomb, 2013), PD has been described as producing "rigidity" across motor, cognitive, and personality domains (Cools et al., 1984, 2001; personality changes reviewed in McNamara, 2011). Specifically, those with PD are unable to shift their current behaviors to consider the best response consistent with environmental demands. An empirical question is whether this shifting deficit in PD also extends to perception. Bistable stimuli are useful tools to investigate how the perceptual system selects a particular interpretation to be represented in awareness and provide the opportunity to examine whether PD is associated with perceptual rigidity; that is, the inability or slowness to consider both perceptual interpretations while observing a bistable stimulus.

Under certain conditions, the visual system cannot reach one particular perceptual interpretation and vacillates between two competing, equally possible percepts. Leopold and Logothetis (1999) proposed an "environment explanation" theory purporting that perceptual reversals during ambiguous perception are the necessary consequences of a generalized high-level exploratory mechanism that directs attention in a way that forces low-level perceptual systems to periodically refresh. Due to the ambiguity of the stimulus, the visual scene requires continual exploration, and reversals in perceptual interpretation consistently occur. This selection theory suggests that attention-related frontal–parietal areas are responsible for initiating perceptual alternations by sending top-down signals to guide activity in visual cortex toward one representation or the other. Fronto-parietal activation during bistable perception has been supported by imaging studies using ambiguous figures and binocular rivalry paradigms (Amir, 2007; Blake and Logothetis, 2002; Britz et al., 2009; Knapen et al., 2011; Sterzer and Kleinschmidt, 2007; Weilnhammer et al., 2013; Wilcke et al., 2009). PD affects the cortico-striato-thalamocortical circuitry including connections to frontal and parietal cortices (for reviews see Christopher and Strafella, 2013; Tinaz et al., 2011), raising the question of whether there is perceptual rigidity in PD; that is, how

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individuals with this disorder perceive bistable figures and experience binocular rivalry.

Researchers have explored the implications of compromised frontal functioning on perceptual ambiguity in other clinical groups, including patients with frontal-lobe damage and schizophrenia (McBain et al., 2011; Ricci and Blundo, 1990; Windmann et al., 2006). Studies describing the role of the frontal lobes in bistable perception found that patients reported significantly fewer reversals when passively viewing a bistable figure when compared to a healthy control group (Yacorzynski and Davis, 1945) and compared to patients with posterior (parietal) lobe damage (Ricci and Blundo, 1990). McBain et al. (2011) reported that individuals with schizophrenia, a psychiatric disorder with known frontal-lobe compromise, were unable to hold one particular face of the Necker cube compared to a matched control group. These studies suggest that poor performance on bistable perception might be considered a frontal sign.

Windmann et al. (2006) expanded earlier findings with patients with frontal-lobe damage by using multiple bistable visual stimuli, including the Necker cube, and two volitional-control conditions in addition to passive viewing: *Hold* one percept as long as possible, and *Switch* between the two percepts as quickly as possible. The investigators predicted group differences if the prefrontal cortex subserved the stabilization of a dominant percept (Hold) and if it subserved the selection among competing inputs and the promotion of perceptual alternations consistent with goals (Switch). They found that compared to a healthy control group, the patients' passive viewing and ability to hold a percept were not impaired, but they were less able to intentionally switch between percepts. Windmann and colleagues suggested that the patients' impairment in the Switch condition could have resulted from a reduced ability to intentionally "let go" of the dominant pattern, which was hypothesized to be a consequence of set-shifting deficits (i.e., cognitive inflexibility). In a study of PD that required a decision on whether an image was monostable or bistable, the subgroup of individuals who made monostable–bistable distinction errors performed significantly more poorly on a measure of attentional set-shifting, the Trail Making Test (B-A), than the subgroup who performed the bistable-image assessment in the normal range (Shine et al., 2012), suggesting that in PD, there may be difficulties in switching between percepts as well as in cognitive switching. A recent imaging study has implicated frontal and parietal hubs of the dorsal attentional network in the ability of those with PD to successfully perform this same behavioral task (Shine et al., 2014). In conjunction with known dysfunction of fronto-parietal attentional networks in PD, the results of these studies together suggest that the perception of bistable images may be compromised in this neurological disorder.

The aims of the present study were to assess whether rigidity extends to perception in non-demented individuals with PD and whether this perceptual rigidity (if it exists) is associated with other rigidity symptoms in PD—specifically, in cognition and personality. Performance of individuals with PD and healthy age-matched adults was compared under three conditions using two bistable stimuli. Necker cube perception and binocular rivalry were examined during passive viewing, and the Necker cube was additionally used for the two volitional control conditions: Hold and Switch. The main hypothesis was that relative to a control group, those with PD would show a reduced ability to volitionally switch between the two possible percepts; that is, they would demonstrate rigidity by holding any one percept for longer than would a normal control group.

2. Materials and methods

2.1. Participants

The study included 28 participants with idiopathic PD and 26 age- and education-matched normal control adults (NC). Participants with PD were recruited from the Parkinson's Disease Clinic at the Boston Medical Center, the Michael J. Fox Foundation Trial Finder, and through local PD support groups. The NC group was recruited from local PD support groups, the Fox Trial Finder, and the community. Potential participants were interviewed about their medical history to rule out confounding diagnoses such as stroke, head injury, and serious medical illness (e.g., diabetes). No participant had undergone surgery affecting the thalamus, basal ganglia, or other brain regions. As part of a larger parent study on perception, cognition, and gait in PD, all participants underwent detailed neuro-ophthalmological examination at the New England Eye Institute in Boston. None of the participants was found on exam or by history to have any ocular illnesses or abnormalities that would have influenced performance on the visually-presented measures of interest. Participant characteristics are provided in Table 1.

Groups were matched for age, education, and ratio of women to men. All participants were non-demented as indexed by their scores on the modified Mini-Mental State Examination (mMMSE, Stern et al., 1987; cut-off score converted to standard MMSE of 27). The two groups significantly differed in their depressive and anxiety symptoms as measured by the Beck Depression Inventory-

Table 1
Participant characteristics for individuals with Parkinson's disease (PD) and matched normal control adults (NC).

	PD $n=28$ 15F,13M	NC $n=26$ 14F,12M	*t*-test	*p*-value	partial η^2	95% CI lower, upper
Age, years	64.2 (6.4)	64.4 (7.7)	$t(52)=.13$	.90		
Education, years	17.5 (2.1)	16.9 (2.4)	$t(52)=1.0$	.32		
MMSE	28.8 (.74)	28.8 (1.0)	$t(51)=.10$	.92		
Near acuity, logMAR [Snellen]	.07 (.23) [20/24]	.03 (.11) [20/22]	$t(51)=.79$	.44		
BDI-II	5.5 (3.6)	2.1 (3.0)	$t(46)=3.5$	**.001**	.21	1.42, 5.28
GDS	4.9 (2.9)	3.4 (3.2)	$t(52)=1.3$	.21		
BAI	5.1 (2.7)	1.5 (1.7)	$t(46)=5.4$	**.001**	.39	2.28, 4.96
WTAR	46.0 (5.3)	44.4 (5.2)	$t(51)=1.1$	.28		
Disease duration, years	5.4 (4.0)	–				
UPDRS total	29.5 (9.9)	–				
Hoehn and Yahr stage	2.0 [1-3]	–				
LED (mg/day)	221.7 (213.6)	–				

All values are reported as means (standard deviations [SD]) except Hoehn and Yahr (H&Y) motor stage, which is reported as median (range). MMSE: Mini-Mental State Examination; BDI-II: Beck Depression Inventory-II; BAI: Beck Anxiety Inventory; WTAR: Wechsler Test of Adult Reading; UPDRS: Unified Parkinson's Disease Rating Scale; LED: Levodopa Equivalent Dose.