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Short Communication

Evidence from cluster analysis for differentiation of antisaccade performance groups based on speed/accuracy trade-offs

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ABSTRACT

Anti and pro-saccade performance in single or mixed contexts was explored in a large sample of young adults (n = 281). ANOVAs were first conducted to evaluate trial type, context and gender effects. A cluster analysis was then used to determine whether subgroups could be identified based on saccadic performance variables. Increased antisaccade errors were observed among females and during mixed-saccade runs. Cluster analysis identified two groups: 1) increased errors clustered with faster latencies and 2) decreased errors clustered with slower latencies. These data offer justification for examining subgroups based on saccadic performance and may help elucidate mechanisms underlying response variability within and between different populations.

1. Introduction

Saccadic eye movement paradigms are valuable for evaluating motor performance and behavioral flexibility (Everling and Fischer, 1998; Hutton, 2008; Sweeney et al., 2007). Basic prosaccades require rapid redirection of gaze toward a visual cue. More cognitively complex antisaccades require suppressing a glance toward a peripheral cue and subsequent generation of a saccade to its mirror image location (Hallett, 1978). An initial glance toward the cue constitutes an error. Antisaccade error rate in healthy participants varies considerably across studies (Hutton and Ettinger, 2006), motivating the question of what factors affect participants' performance.

Antisaccade error rates may be impacted by individual differences like gender (Ettinger et al., 2005) and schizotypal symptoms (Gooding, 1999; Holahan and O'Driscoll, 2005), as well as saccadic latencies (Ettinger, et al., 2005) and the context in which trials are presented (Cherkasova et al., 2002). Within antisaccade tasks, higher error rates are associated with decreased correct response latencies (Evdokimidis et al., 2002), indicating a possible speed/accuracy trade-off. Between tasks, higher antisaccade errors are associated with decreased prosaccade latencies (Ethridge et al., 2009; Ettinger, et al., 2005), indicating a link between failed inhibition and speed of visual orienting (Reilly et al., 2008). Antisaccade errors also vary as a function of context. Higher error rates occur during tasks mixing pro- and anti- saccades within the same run as compared to tasks requiring only a single type of saccadic response (Ethridge et al., 2009).

The present study sought to characterize factors associated with antisaccade error rate in a large sample of healthy young adults using mixed- and single-saccade type designs. The goal was to determine whether saccadic measures could be used to facilitate the identification of performance subgroups (subgroups that differ on speed/accuracy tradeoff).

2. Methods

Right-handed undergraduate participants (n = 281; Mean age = 19.2 years, SD = 1.3; 63.3% female) had no history of psychiatric illness or severe head trauma (self-report). The study was approved by the UGA IRB; written informed consent was obtained. IQ was estimated using the WASI (Wechsler, 1999). Clinical symptoms were assessed with the Schizotypal Personality Questionnaire (SPQ; Raine, 1991) and were analyzed as total score and cognitive-perceptual,

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interpersonal, and disorganized deficit subscales (Raine, et al., 1994). The Beck Depression Inventory–II (BDI–II; Beck, 1996) and Customary Drinking and Drug Use Record (Brown et al., 1998) also were used for clinical assessment.

Participants completed a 'gap' version of anti- and pro-saccade tasks (in which there was a temporal gap between fixation and target stimuli) in three runs (see Supplementary Materials for additional details). The purpose of using gap saccade tasks was to reduce floor effects on antisaccade error rate (McDowell and Clementz, 1997). Each run alternated between 22 second blocks of a single trial type: (i) 6 antisaccade blocks alternated with 7 blocks of central fixation (anti-fix), (ii) 6 prosaccade blocks alternated with 7 fixation blocks (pro-fix), and (iii) 6 antisaccade blocks alternated with 7 prosaccade blocks (anti-pro). Saccade blocks contained 8 trials with an equal number of left and right cues. The anti- and pro-fix runs were "single" saccade runs, and the anti-pro run was the "mixed" saccade run. Eye movements were recorded at 500 Hz using an Eye Trak model 310 (Applied Science Laboratories, Waltham, MA) and were scored for percentage correct and reaction time (Dyckman and McDowell, 2005).

First, ANOVAs were conducted to evaluate the effect of trial type, context and gender on performance. Then, a two-step cluster analysis procedure was used to determine whether subgroups of participants could be identified based on saccadic performance variables (Zhang et al., 1996). In the first step, individuals were grouped into leaf nodes of a tree data structure on the basis of the similarity of each individual, and a cluster feature (CF) tree was constructed. In the second step, the leaf nodes of the CF tree were grouped again using an agglomerative hierarchical clustering method to verify cluster solutions. Schwarz's Bayesian Criterion (BIC) was used to determine the final cluster solution. Comparisons were made between individuals in different clusters on WASI and clinical ratings to evaluate whether saccadic response strategy was associated with important individual difference variables.

Table 1
Cluster analysis solution.

Variable	Group 1		Group 2		Effect size
	N = 156 (104 female)		N = 100 (64 female)		
	Mean	SD	Mean	SD	
Pro-single PE	0.2	1.0	0.2	0.7	0.0
Pro-mixed PE	0.3	1.4	0.8	2.8	−0.3
Anti-single PE	20.6	13.3	41.2	17.0	−1.4*
Anti-mixed PE	25.1	14.4	44.4	16.4	−1.3*
Pro-single RT	150.8	15.5	127.3	10.0	1.8*
Pro-mixed RT	157.4	16.2	131.2	11.0	1.8*
Anti-single RT – cor	246.3	32.9	214.2	30.9	1.0*
Anti-mixed RT – cor	245.8	35.2	217.4	27.4	0.9*
Anti-single RT – err	195.5	40.5	148.5	19.1	1.5*
Anti-mixed RT – err	190.0	37.8	146.1	23.3	1.4*
WASI – S	28.1	3.7	27.9	2.8	0.1
WASI – V	62.3	6.5	62.4	6.2	0.0
BDI	8.1	7.3	6.4	4.8	0.3
SPQ: Total	16.2	11.6	14.6	8.5	0.2
SPQ: C-P	6.8	5.7	5.5	3.9	0.3
SPQ: I	6.7	6.1	6.4	4.9	0.1
SPQ: D	4.3	3.8	3.9	3.2	0.1
EtOH – life ep	96.4	134.7	111.9	180.9	−0.1
EtOH – ep/month	5.5	6.1	5.4	5.7	0.0
EtOH – drink/ep	3.9	4.4	3.6	3.5	0.1

Effect size calculated using pooled standard deviation. Single, single task; Mixed, mixed task; PE, percent errors; RT, latency (ms) for correct (cor) and errors (err). WASI, Wechsler Abbreviated Scale of Intelligence, Spatial Reasoning (S) and Vocabulary (V). BDI, Beck Depression Inventory; SPQ, Schizotypal Personality Questionnaire Total, cognitive-perceptual (C-P), interpersonal (I), and disorganized deficits (D) subscales. Customary Drinking and Drug Use (EtOH) for life time drinking episodes (life ep), average number of drinking episodes per month (for previous 3 months; ep/month) and number of drinks per episode (drink/ep).

* Between group F tests significant at $p < .001$.

3. Results

3.1. Saccade task variable analyses

Error rate was analyzed using trial type (antisaccade, prosaccade) by context (single, mixed) by gender (male, female) ANOVA. For error rate, there were main effects of trial type, $F(1,276) = 678.4$, $p < .001$, context, $F(1,276) = 27.2$, $p < .001$, and gender, $F(1,276) = 6.7$, $p < .01$, and significant trial type by context, $F(1,276) = 24.3$, $p < .001$, and trial type by gender, $F(1,276) = 5.4$, $p < .02$, interactions. There were more errors on anti- than pro-saccade trials, and more errors in the mixed than single conditions. The latter effect was more pronounced for anti- (single M = 26.8%, SD = 18.4; mixed M = 30.6%, SD = 18.5) than pro-saccades (single M = 0.2%, SD = 0.9; mixed M = 0.6%, SD = 2.3). Females (antisaccade M = 30.5%, SD = 17.3; prosaccade M = 0.5%, SD = 1.3) made more errors than males (antisaccade M = 25.5%, SD = 16.6; prosaccade M = 0.3%, SD = 0.8), again, more pronounced for antisaccades.

Saccade latencies were analyzed using a trial type (correct prosaccade, correct antisaccade, error antisaccade) by context (single, mixed) by gender (male, female) ANOVA (25 subjects were excluded based on no antisaccade errors). For latency, there was a main effect of trial type, $F(2,508) = 952.1$, $p < .001$. Correct antisaccades (M = 234.8 ms, SD = 35.5) had the slowest latencies, followed by error antisaccades (M = 175.0 ms, SD = 40.0) and prosaccades (M = 144.4 ms, SD = 18.6), $t's > 10.4$, $p's < .001$.

3.2. Cluster analysis

A two-step cluster analysis using the saccade performance variables revealed two unique clusters consisting of 156 and 100 participants, respectively (Table 1). Group differences were observed for all saccade variables except prosaccade percentage correct. Participants in Group 2 had more antisaccade errors and faster latencies across all trial types then participants in Group 1 (see Fig. 1). The groups did not differ on WASI, BDI, SPQ or alcohol use variables (see Table 1).

4. Discussion

The results of the present study suggest that antisaccade performance and speed of visual orienting are related — higher error rates clustered with faster saccadic response times (and lower error rates clustered with slower saccadic response times). This coupling suggests that (1) participants tend to use one of two strategies for performing antisaccade tasks: to emphasize speed or to maximize accuracy; and/or (2) that error rate may be secondary to speed of saccade generation (Klein et al., 2000). This pattern in healthy (Ethridge et al., 2009; Ettinger et al., 2005; Evdokimidis et al., 2002) and in schizophrenia (Harris et al., 2006) participants suggests that heightened visual orienting to a salient peripheral stimulus, manifested in speeded saccade latencies, may predispose to greater risk of antisaccade error generation independent of psychiatric status.

Saccadic performance in healthy participants is heterogeneous, but neither IQ nor clinical measures were associated with the saccadic performance patterns. In the current study of healthy, young adults the IQ range was restricted and the SPQ scores were both restricted and low (see also Klein et al., 2000). Restriction of range may have limited our ability to resolve the relationships between the clinical and saccadic variables. It may be, however, that the relationship between speed of visual orienting and inhibitory ability is independent of cognitive and/or psychiatric status.

Gender and context were associated with saccadic performance differences. Females made more saccadic errors than males while their response times do not differ (Ettinger et al., 2005). Mixed

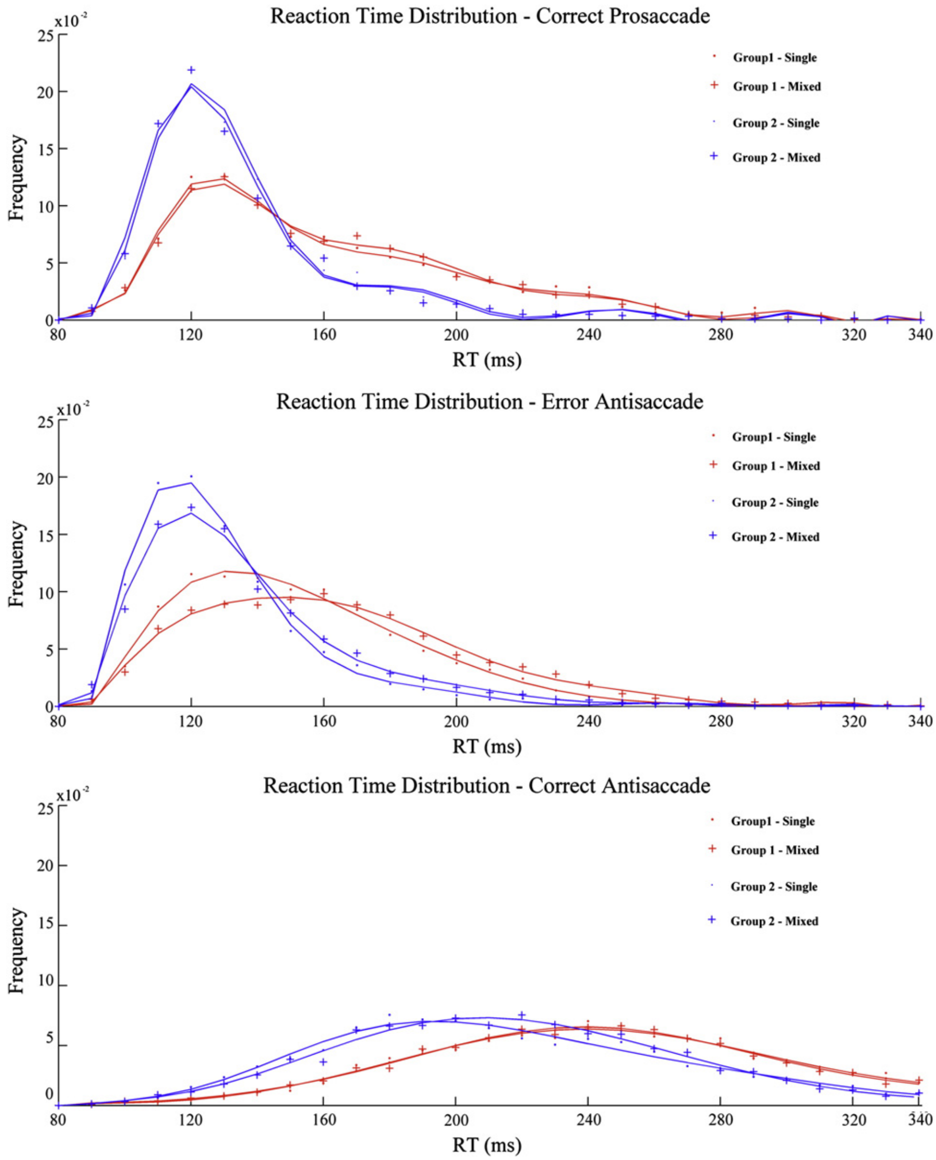

Fig. 1. Distribution of saccade reaction times as a function of saccade type (correct prosaccade, error antisaccade, correct antisaccade), cluster membership (cluster group 1 = low error rate in red, cluster group 2 = high error rate in blue), and trial type (single (dot symbol), mixed (plus symbol)).

saccade paradigms yielded more errors than single trial paradigms (Cherkasova et al., 2002; Dyckman et al., 2007; Ethridge et al., 2009). As expected, error responses were more common when performance requirements were variable within a task (mixed versus single condition), an effect that was more pronounced for the more cognitively complex antisaccades.

These data offer further justification for examining subgroups based on saccadic behavioral performance. This may be especially true with regard to gender differences in antisaccade performance. Despite the repeatability of this effect, little is known about its neurophysiological correlates. Future studies aimed at identifying distinct subgroups based on saccadic performance may help to elucidate mechanisms for response variability within and between different participant populations. Inspection of prosaccade and antisaccade error reaction time distributions for persons in the fast visual orienting-high error rate and slow visual orienting-low error rate clusters indicates striking differences in management of context. High error cluster members were seemingly insensitive to context while the low error rate cluster members seemed to adjust their response strategy to changing situational demands. Whether groups identified by saccadic performance features differ on other behavioral, cognitive and clinical measurements is an important question for future research.

Appendix A. Supplementary data

Supplementary data to this article can be found online at doi:10.1016/j.ijpsycho.2012.03.008.

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