Selective Attention Demand Mediates Rule-Based Categorization Deficits in Focal Basal Ganglia Lesion Patients

Shawn W. Ell[1], Andrea Weinstein[2], J. Vincent Filoteo[3], W. Todd Maddox[4], and Richard B. Ivry[2]

[1]University of Maine, [2]UC Berkeley, [3]UC San Diego/VASDHS, [4]University of Texas

BACKGROUND

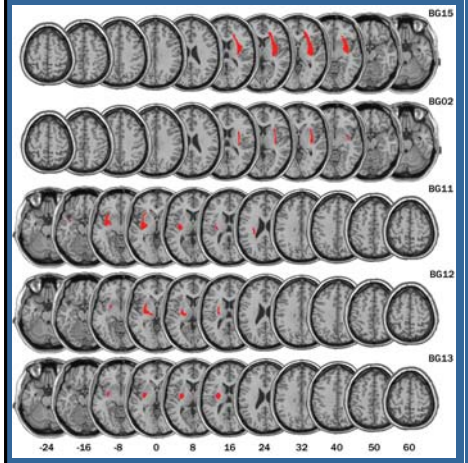
• Basal ganglia dysfunction impairs learning in rule-based categorization tasks where learning depends on the use of an explicit, hypothesis-guided strategy (Ashby & Ell, 2001).

• Filoteo et al. (in press) report that this impairment in Parkinson's disease may be limited to rule-based tasks that place demands upon selective attention.

• Ell et al. (2006) found that patients with focal basal ganglia lesions are impaired on a rule-based task that places minimal demands upon selective attention.

• We ask here if the severity of the impairment in patients with focal basal ganglia lesions increases with selective attention demands.

LESION RECONSTRUCTIONS



Lesion reconstructions for 5 of the 6 patients generated with the MRIcro software package (Rorden & Brett, 2000) using procedures described in (Brett, Leff, Rorden, & Ashburner, 2001).

• Evidence of putamen involvement in all six patients
• Lesion extended into the caudate nucleus for one patient (BG01 – not pictured)
• Damage extends into white mater (internal, external, and extreme capsules) for several patients
• One patient may have had an additional stroke in the thalamic region (BG12)

METHOD

Participants

	BG† (n=6, 1 F) 4 left, 2 right		CO° (n=7, 3 F)	
	Mean	SEM	Mean	SEM
Age	61.2	4.7	63.6	2.4
Education	14	1.3	14.9	.7
NART	112	4	121.9	2.4
SS-forward (raw)	7.5	.7	7.1	.7
SS-backward (raw)	6.8	1	7.9	.7
DS-forward (raw)*	9.2	.8	12.7	.6
DS-backward (raw)	6.3	.7	8.7	1.0
CWI-Inhibition (s)	77	6.9	63.1	6.8
CWI-Inhibition/ Switching (s)	74.3	5.2	64.3	6.5
WCST-nCategories	4.4	1	5.1	.9
WCST-Perseverative Errors	19.8	5.1	12.6	4.1
WCST-Set Loss Errors	.8	.2	1	.4

†Focal basal ganglia lesion participants °Age and education matched controls
Note: NART = National Adult Reading Test; SS = Spatial Span; DS = Digit Span; CWI = Color-Word Interference subtest (DKEFS Delis et al., 2001); WCST = Wisconsin Card Sorting Test
**significant group difference (α = .004, corrected for multiple comparisons).*

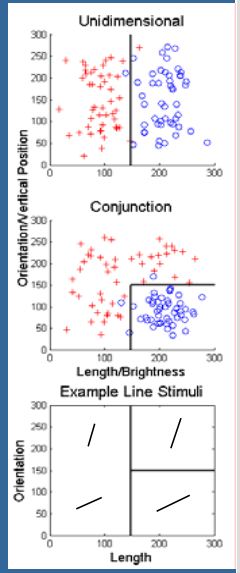
Tasks and Procedure

• Two categorization tasks varying in selective attention demands
  - Unidimensional > Conjunction

• Stimuli:
  - Lines varying in length and orientation
  - Lines varying in brightness and position

• Trial:
  - Stimulus remained present until response
  - Feedback provided after each response

• General:
  • Participants instructed to divide stimuli into two categories by trial-and-error
  • Both tasks tested in single session, separated by neuropsychological assessment battery
  • Each task included three, 96-trial blocks



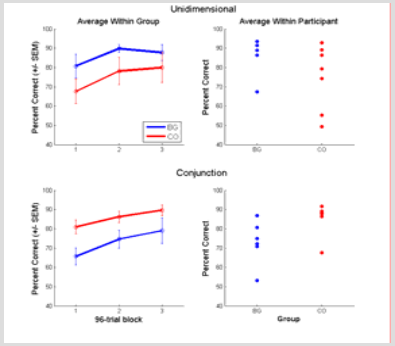
• Category 1 stimuli are plotted in red, category 2 in blue
• The solid lines represent the optimal decision bounds.

RESULTS

Accuracy-Based Analyses

• Trend for the CO participants to perform worse than the BG patients in the Unidimensional task.
  - 4/7 COs performed worse than average BG

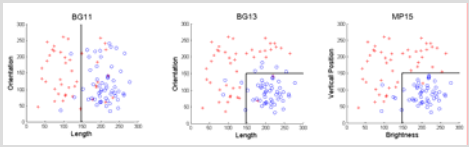
• BG patients impaired on the Conjunction task.
  - 5/6 BGs performed worse than average CO



Model-Based Analyses

To investigate the decision strategies used to learn the categorization tasks, models were fit assuming participants used one of three strategies:

1. Unidimensional Classifier (UC - left panel)
2. Conjunctive Classifier (CC - right panels)
3. Random responder (RR)



The scatterplots are representative data sets from two patients (BG11, BG 13) and one control (MP15) during the final block in the Conjunction task. Category A and B responses are plotted in red and blue, respectively. The solid lines are the estimated decision criteria.

Distribution of Best-Fitting Models

• Unidimensional (UD) Task
  - By block 3, all BG participants were using optimal strategy (UC)
  - By block 3, 2/7 COs were using suboptimal RR strategy

• Conjunction (CJ) Task
  - By block 3, 6/7 COs were using optimal strategy (CC)
  - By block 3, only 3/6 BGs were using optimal strategy (CC)

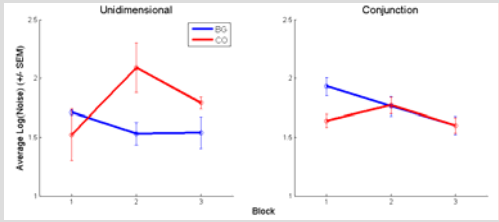
		Basal Ganglia			Control		
		Block					
	Model	1	2	3	1	2	3
UD Task	UC	5	6	6	3	5	5
	RR*	1			4	2	2
CJ Task	UC	3	2	2	3	1	1
	CC	2	3	3	4	6	6
	RR	1	1	1			

Note. UC=Unidimensional Classifier; CC=Conjunctive Classifier; RR=Random Responder
Excluding RRs: eliminated BG advantage in UD task

Variability in the Decision Criteria (i.e., Criterial Noise)

• Unidimensional Task
  - COs more variable than BGs in the application of their decision strategies late in learning

• Conjunction Task
  - BGs more variable than COs in the application of their decision strategies early in learning



Note. Participants classified as responding randomly (RR model) were excluded from this analysis

SUMMARY

• Patients with focal basal ganglia lesions were impaired in the Conjunction task, but not the Unidimensional task.
  - There was a trend for control participants to perform worse than the basal ganglia patients in the Unidimensional task, but this effect was driven primarily by two controls.

• The model-based analyses suggest that the impairment in the Conjunction task may be due to the use of suboptimal decision strategies throughout the task.
  - Variability in decision processes, perhaps reflecting an increased tendency to switch decision strategies, may also contribute early in learning.

• These results replicate previous work demonstrating that patients with focal basal ganglia lesions were impaired in a four-category, Conjunction task (Ell et al., 2006).

• These results are opposite those observed in PD patients (Filoteo et al., in press) and raise the intriguing possibility that focal basal ganglia lesions and disorders that alter dopamine systems (i.e., PD) might have opposite effects on rule-based category learning.

References

Ashby, F. G., & Ell, S. W. (2001). The neurobiology of human category learning. *Trends in Cognitive Science, 5*, 204-210.

Brett, M., Leff, A. P., Rorden, C., & Ashburner, J. (2001). Spatial normalization of brain images with focal lesions using cost function masking. *NeuroImage, 14*, 486-500.

Delis, D.C., Kaplan, E., & Kramer, J.H. (2001). *Delis-Kaplan Executive Functioning System.* San Antonio, TX: The Psychological Corporation.

Ell, S.W., Marchant, N.L., & Ivry, R.B. (2006). Focal putamen lesions impair learning in rule-based, but not information-integration categorization tasks.

Filoteo, J.V., Maddox, W.T., Ing, A.D., & Song, D.D. (2007). Characterizing rule-based category learning deficits in patients with Parkinson's disease. *Neuropsychologia. 45*, 305-320.

Rorden, C., & Brett, M. (2000). Stereotaxic display of brain lesions. *Behavioural Neurology, 12*, 191-200.

Acknowledgements

This study was supported by grants NS047884 to SWE and NS30256 to RBI from the National Institutes of Health.

Thanks to Donatella Scabini, Leslie Shupenko, and Alex List for their assistance in the recruitment and assessment of the patients. Thanks to Andrea Jang for her assistance with data collection and to Matthew Brett and Mark D'Esposito for their assistance with the analysis of the MRI scans.