Poster presented at the meeting of the Cognitive Neuroscience Society, San Francisco, CA, March, 1994. Abstract published in *Journal of Cognitive Neuroscience*, 1994, Vol. 6.

Task Switching In Patients With Prefrontal Cortex Damage

Joshua Rubinstein[1], Jeffrey E. Evans[2], & David E. Meyer[3]

[1]Center for Neuroscience, University of California, Davis, CA. [2]Rehabilitation Psychology & Neuropsychology, University of Michigan Medical Center, Ann Arbor, MI. [3]Department of Psychology, University of Michigan, Ann Arbor, MI.

Introduction

Many researchers have suggested the existence of a central executive which coordinates routine tasks into complex, novel behaviors. Furthermore, these executive functions are thought to be mediated by the prefrontal cortex. Task switching occurs when a subject performs two different tasks in succession. Switching between routine tasks requires additional processing time and is assumed to be controlled by the central executive. Several researchers have studied task switching performance in normal subjects (Allport, Styles, & Hsieh, 1992; Rubinstein, Meyer, & Evans, in preparation) and in brain damaged patients (Downes et al., 1993; Owen et al., 1993). The experiments presented here examine task switching performance in six subjects with lesions in different areas of the prefrontal cortex. Only the subject with damage to dorsolateral prefrontal cortex showed a severe task-switching deficit. Two additional experiments examine possible causes of this deficit.

Method

Subjects. The control subjects were undergraduates at the University of Michigan who received either payment or course credit for their participation. The six patients tested had focal lesions in different areas in the prefrontal cortex. Table 1 lists the lesion location for each patient.

Table 1.
Lesion locations for each of the six frontal lobe patients tested in Experiment 1.

Patient	Site of lesion	Cause of lesion
TS	left dorsolateral	arteriovenous malformation
ED	left mesial	*ACA aneurysm
CV	right mesial	*ACA aneurysm, ant. bleed
VK	right mesial	*ACA aneurysm
MC	right frontal pole	astrocytoma (resected)
JE	bilateral whitematter (mostly right frontal)	glioblastoma, right whitematter bleed

* anterior communicating artery

General methodology. Task-switching times were measured by comparing response times between two pure blocks and one mixed block. In each pure block subjects performed a series of trials of one type of task (e.g. match to number in pure block 1, and match to shape in pure block 2). In the mixed block subjects alternated between both tasks (e.g. number, shape, number, shape and so on). Switching times were calculated by subtracting the two pure blocks' baseline (average) RT from the mixed block's RT.

Experiment 1

Task switching was assessed by having subjects switch between different sorting rules. Figure 1 shows an example of a trial. Stimuli were similar to those used in the Wisconsin Card Sorting Test. There were four dimensions (number, shape, shading, and size) that subjects used when sorting, with four values on each dimension. The mixed blocks required subjects to alternate between two sorting rules (e.g. number, shape, number, shape, and so on).

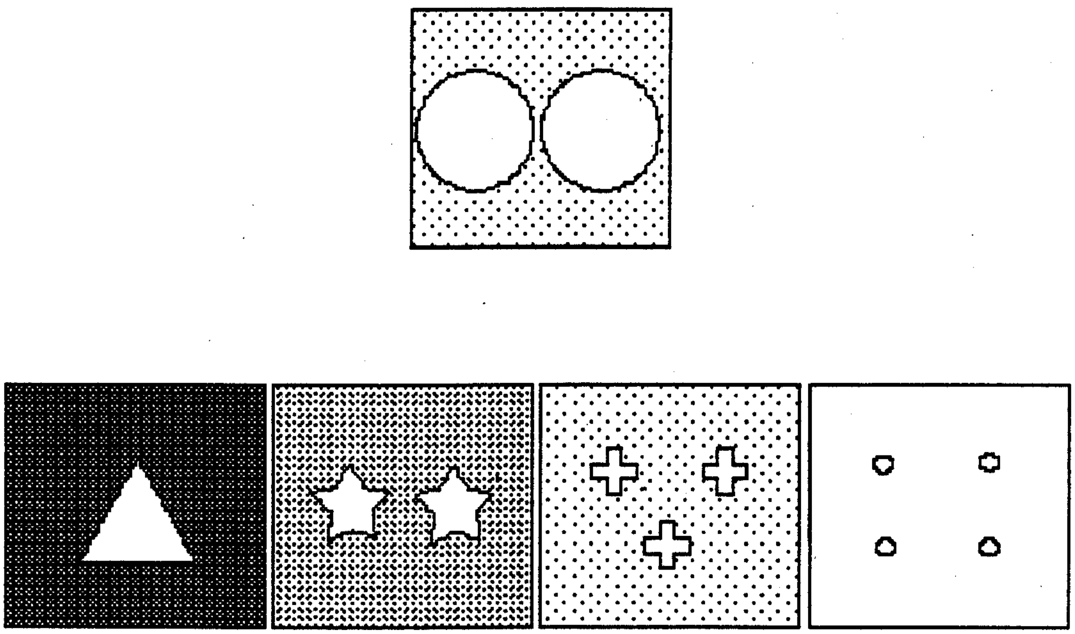

Figure 1. An example of a trial used in Experiments 1 and 3. Note that the test stimulus matches each of the four target stimuli below it on one dimension each (number, shape, shading, or size).

Materials. Stimuli were constructed on index cards. Four target cards were presented in front of the subject. Each block required a deck of 24 test cards which the subject held in one hand. The subject placed each test card next to the matching target card according to the relevant stimulus dimension.

Results of Experiment 1

There was a significant effect of switching. Figures 2 and 3 show the control group switching times and pure task response times for the two types of switching: between number & shape (fig. 2), and between shading & size (fig. 3). Figures 2 and 3 also show the switching times for the six prefrontal lesion patients. Switching times were normalized with respect to pure task times to reduce the effects of overall slowness due to brain damage. Only patient TS produced normalized switching times that fell outside of the 99% confidence interval for the control group, suggesting that only TS produced significantly slower switching times.

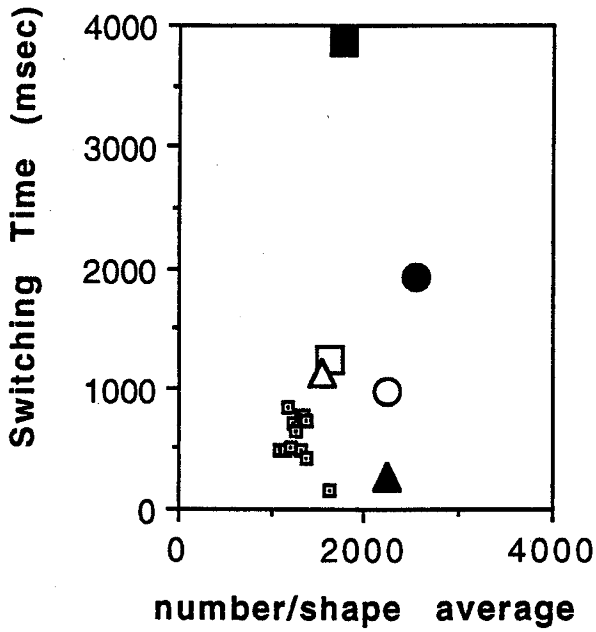

Figure 2. Pure-task response times and switching times for sorting based on number and sorting based on shape. The baseline (x-axis) is the average response time for pure number and pure shape blocks.

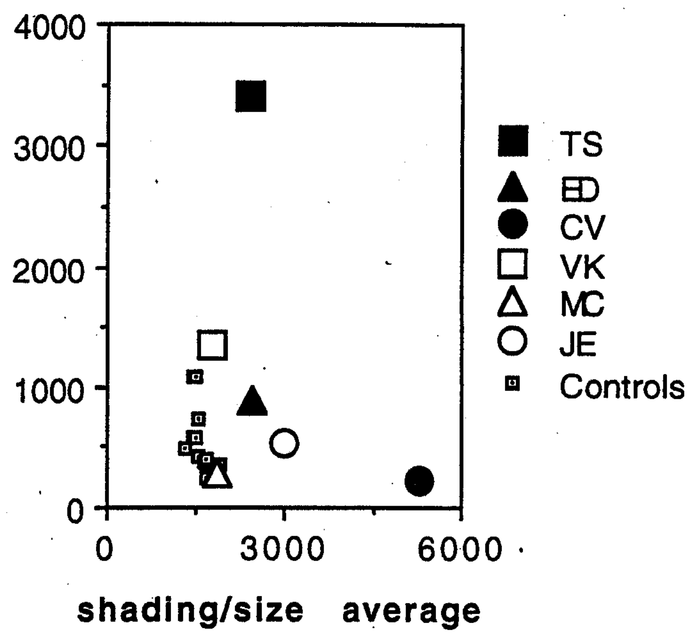

Figure 3. Pure-task response times and switching times for sorting based on shading and sorting based on size. The baseline (x-axis) is the average response time for pure shading and pure size blocks.

Experiment 2

Experiment 2 tests the hypothesis that the large switching times produced by TS were due to his inability to ignore interfering stimuli. In this experiment, subjects matched test stimuli to targets based on shading or shape. Figure 4 shows an interference trial in which each test stimulus can match the targets on both dimensions. Figure 5 shows a no-interference trial in which each test stimulus only matches the targets on the relevant dimension, and doesn't match any target stimulus on the irrelevant dimension. This experiment was run on a Macintosh computer with similar stimuli to those used in Experiment 1.

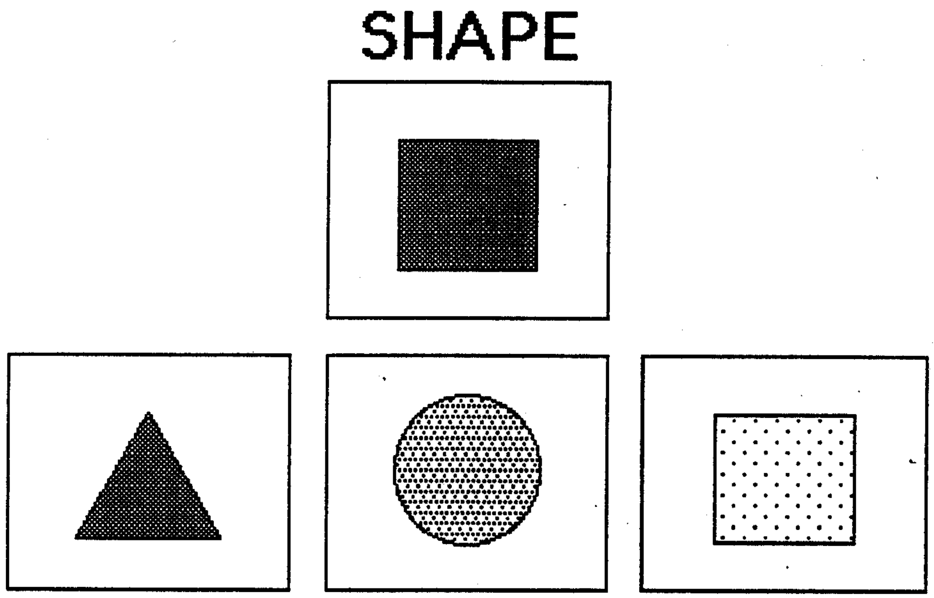

Figure 4. An example of an interference shape trial. Each trial in this condition requires subjects to match according to shading or shape. Note that the test figure (above) can match the target on the far right according to shape and can match the target on the far left according to shading.

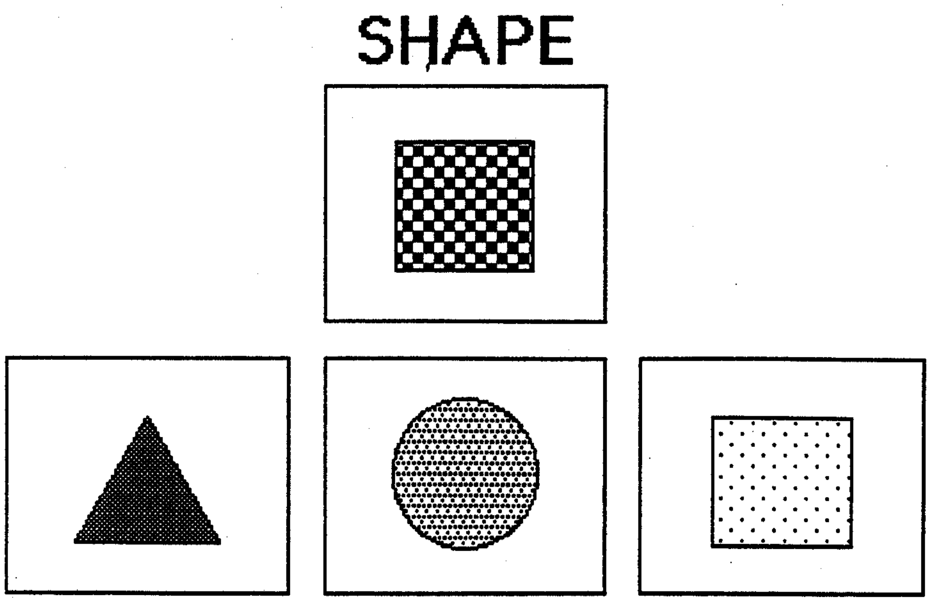

Figure 5. An example of a no-interference shape trial. Each trial in this condition requires subjects to match according to shading or shape. Note that the test figure (above) can match the target on the far right according to shape but cannot match any of the targets according to shading.

Results of Experiment 2

Figure 6 shows the switching times. Both the control group and TS showed significant effects of interference on switching. Difference scores were calculated between the interference and no-interference conditions. TS produced difference scores that fell outside the 99% confidence interval for the control group, suggesting that TS was affected by the presence of interfering stimuli more than the controls were. Furthermore, in the no-interference condition TS produced switching times that were not significantly different than those of the control group.

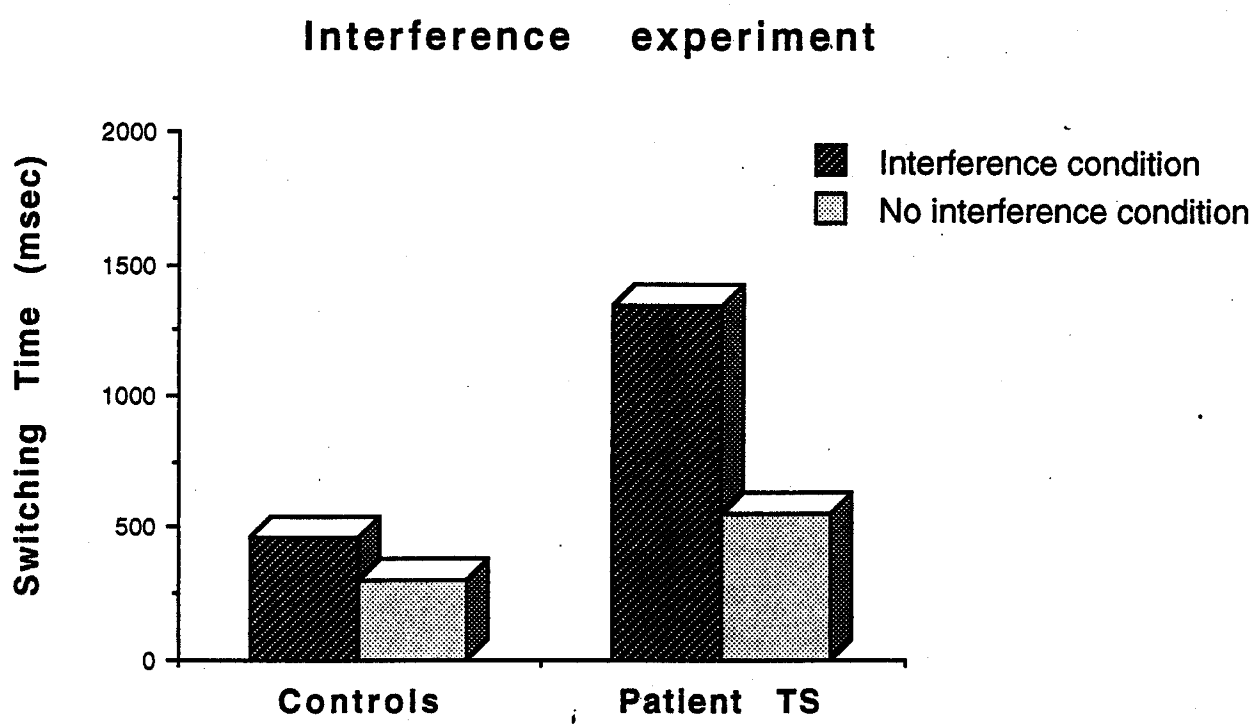

Figure 6. Results of the interference experiment. Interference from the irrelevant dimension slowed switching times for both the control group and TS. The interference manipulation affected TS more than it did the controls.

Experiment 3

Rogers and Monsell (1992) have shown that increasing inter-trial intervals decreases switching times. Experiment 3 tests whether TS benefits from longer inter-trial delays as much as normal controls do. In this experiment, subjects performed task switching with and without a 1200 msec inter-trial interval. The stimuli and design from Experiment 1 were presented using a Macintosh computer.

Results from Experiment 3

Figure 7 shows the switching times. Both the control group ($p < .054$) and TS showed effects of having a long inter-trial delay on switching. Difference scores were calculated between the delay and no-delay conditions. TS produced difference scores that fell outside the 99% confidence interval for the control group, suggesting that TS was affected by the presence of an inter-trial delay more than the controls were.

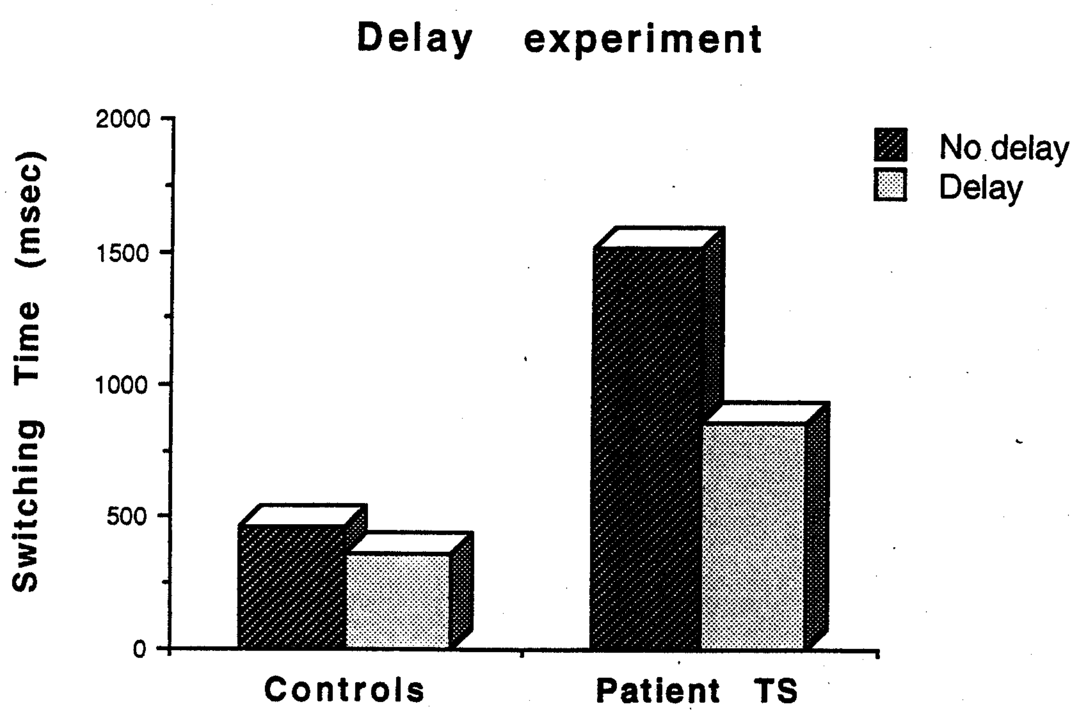

Figure 7. Results of the delay experiment. Both the control group and TS produced shorter switching times when there was a 1200 msec delay between trials. The delay manipulation affected TS more than it did the controls.

Conclusions

1. The central executive control of task switching can be measured directly providing specific data on executive functions.

2. The prefrontal cortex contains functional subdivisions. Only the dorsolateral area controls task switching.

3. Task switching in normal subjects is affected by interference from irrelevant stimulus dimensions. More interference leads to longer switching times.

4. Prefrontal dorsolateral cortex (PDC) damage results in a larger interference effect than that found in normal controls. This suggests that the PDC controls the ability to overcome interference during task switching.

5. Task switching in normal subjects is affected by the amount of delay present between trials. Longer delays lead to shorter switching times.

6. PDC damage results in a larger inter-trial delay effect than that found in normal controls. This suggests that the nature of TS's task-switching deficit is time-dependent, and may be related to the time-course of rule activation and/or goal memory.

References

Allport, A., Styles, E., & Hsieh, S. (1992, July). Non-spatial orienting of attention: Exploring the dynamic control of tasks. Paper presented at the meeting of Attention and Performance XV, Erice, Sicily.

Downes, J., Sharp, H., Costall, B., Sagar, H., & Howe, J. (1993). Alternating fluency in Parkinson's disease: An evaluation of the attentional control theory of cognitive impairment. Brain, 116, 887-902.

Owen, A., Roberts, A., Hodges, J., Summers, B., Polkey, C., & Robbins, T., (1993). Contrasting mechanisms of impaired attentional set-shifting in patients with frontal lobe damage or Parkinson's disease. Brain, 116, 1159-1175.

Rogers, R., & Monsell, S. (1992, April). Task-set reconfiguration during a predictable task switch. Paper presented at the meeting of the Experimental Psychology Society, Oxford, England.

Rubinstein, J., Meyer, D., & Evans, J. (1994). Executive control of cognitive processes in task switching. Unpublished manuscript.