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Selective Effects of Prior Motivational Experience on Current On-Line Control of Attention

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This study examined the influence of prior motivational experience on the efficiency of executive attention control during performance of a task set reconfiguration task (Rogers & Monsell, 1995). Results revealed that motivation manipulations selectively affected attention switching mechanisms, but did not influence either inhibition of crosstalk from competing stimuli, or basic response execution time. This provides additional evidence for distinct attentional systems involved in resolution of response and perceptual competition. Speculations regarding the neural systems that mediate both motivation and attention switching are considered, pointing to a possible involvement of dopaminergic influences on the ventral striatum.

Recently, there has been considerable interest in mechanisms of attention and action control (Monsell, 1996; Shallice, 1994; Stuss, Shallice, Alexander, & Picton, 1995). Norman and Shallice (1986) proposed that performance is controlled by two mechanisms operating on hierarchically organized action schemata: a competitive, lower level *contention scheduling* system that coordinates routine actions by allowing only the most strongly activated schema to direct behavior; and a higher level, *supervisory attentional system* (SAS) for executive control functions (e.g., voluntary switching and inhibition), that operates top-down fashion to bias contention scheduling. Evidence consistent with this framework comes from studies of patients with frontal lobe damage associated with loss of supervisory control (perseveration, utilization behavior) (Shallice, 1988), attention lapses in normal individuals (Reason, 1984), and reaction time (RT) costs when normal subjects intentionally switch attention between alternative tasks (Allport, Styles, & Hsieh, 1994; Rogers & Monsell, 1995; Segalowitz, Poulsen & Segalowitz, in press).

Researchers have only recently begun to explore the role of motivation in on-line attentional processes (e.g., Derryberry & Tucker, 1994). For example, Derryberry (1993) proposed that motivation guides cognition by modulating selective attention. His results suggested that motivation can selectively orient attention toward positive and negative incentive stimuli and influence the breadth of attentional focus, thereby serving an adaptive, self-regulatory role in attention. To date, however, researchers have not directly addressed the effect of motivation on the *voluntary* control of attention. In line with Norman and Shallice's (1986) model, we propose that the ease with which executive intervention (SAS) can initiate a voluntary switch and inhibit an involuntary switch during performance is, in part, a function of the relative motivational significance of competing action schemata and stimuli developed through prior experience.

The present study combined Rogers and Monsell's (1995) attention switch paradigm with motivation manipulations modelled on Derryberry (1993) to investigate the effect of prior motivational experience on attention switching and inhibition. In brief (see Method), subjects first received blocked training on two alternative left/right button press response sets (i.e., letter judgment—vowel/consonant versus digit judgment—even/odd) to compound stimuli of letter or digit targets paired with neutral foils (e.g., *2 or G%). Subjects then performed a switch task where every second trial required a switch from the letter to digit task, or vice versa, and where the letter or digit target was paired with a neutral foil (as in training) on one third of the trials, and with a competing foil (e.g., 3A) on remaining trials. Thus, subjects had to intentionally switch between two judgment tasks while inhibiting perceptual and response competition. To explore the effect of prior motivational experience, subjects were situated in a game context where the object was to accrue points. Task motivation (high vs low motivated) was manipulated during training by assigning differential points (6 vs 2, making one task more valuable) for fast and accurate responses on letter versus digit trials. In the subsequent switch task, letter and digit judgments were of equal value (4 points).

This paradigm yielded three RT indices of voluntary attention control and one RT index of simple response execution for each judgment task: (1) switch-without-crosstalk cost (*SW Cost*), operationally defined as the difference in RT on switch/neutral foil versus nonswitch/neutral foil trials; (2) crosstalk-without-switch cost (*XT Cost*), RT difference on nonswitch/competing foil versus nonswitch/neutral foil trials; (3) switch-with-crosstalk cost (*SWXT Cost*), RT difference on switch/competing foil versus nonswitch/neutral foil trials; and (4) simple task execution time (*SIMPLE RT*), RT on the nonswitch/neutral foil trials.

By comparing the magnitude of the three attention indices as a function of task motivation, we investigated whether differential motivational experience affected mechanisms related to attention switching and/or inhibition of crosstalk. Comparison of SIMPLE RT examined whether motivational experience affects simple response execution times when no attention challenge is present.

Method

Subjects. Participants were 16 paid female volunteers, aged 19–32 years (M = 23.2).

Materials and procedures. Stimuli were target–foil pairs (e.g., A3, 9E, G#, ?6) presented on a computer monitor (for counterbalancing, see Rogers & Monsell, 1995, Experiment 1, Crosstalk Condition). Targets were either letters (A, E, I, U; G, K, M, R) or digits (2, 4, 6, 8; 3, 5, 7, 9). Foils were letters, digits, or neutral symbols (%, #, ? *). Using a left/right button press, subjects performed vowel/consonant (letter task) or even/odd (digit task) judgments. To learn the appropriate button presses, subjects received 8 blocks of 24 letter trials followed by 24 digit trials, or vice versa. During this *training,* the letter or digit target was always paired with a neutral foil and presented in the center of the monitor.

In the *switch task,* the target–foil stimulus pair was presented in one of four quadrants on the computer monitor. Quadrant position cued subjects to perform either the letter or digit task (e.g., letter task in the top quadrants; digit task in the bottom). Stimulus pairs were presented in clockwise rotation resulting in a regular alternation of *nonswitch* trials, on which subjects performed the same task as on the previous trial, and *switch* trials, on which subjects switched attentional focus from letter to digit task, or vice versa. Targets were paired with neutral foils on one third of trials, and with competing foils (e.g., digit foil with letter target) on the remainder. Stimuli remained on screen until response (deadline = 5000 ms; RSI = 450 ms). Subjects completed a 96-trial practice block, followed by eight 48-trial experimental blocks (12 warm-up and 36 experimental). Following a 10-min break, subjects repeated this sequence, yielding 576 experimental trials per subject.

Subjects were situated in a computer-game environment where the objective was to accrue points by making correct, fast responses, referred to as *zaps* (defined as RT faster than the 75th percentile RT of comparable trials on the previous block, thereby ensuring equal probability of a zap across letter and digit trials during training, and across letter and digit switch and nonswitch trials during the switch task). Eight subjects were randomly assigned to a letter-motivated (LM) group, and 8 to a digit-motivated (DM) group. During training, LM subjects earned 6 points for each letter zap (high-motivated task) and 2 points for digit zaps (low-motivated task), and DM subjects the reverse. During the switch task, letter and digit zaps were of equal, 4-point value. During training and the switch task, subjects received auditory feedback following each zap (2, 4, or 6 beeps for points earned), summary performance feedback after each 48-trial block, and a 10-point bonus for making fewer than 5 errors/block.

Results

Individual subject data was Winsorized (top 10% for each condition). In individual subject analyses, every subject had significant effects ($p < .006$) of crosstalk and switch, confirming the basic attention outcomes of this paradigm.

Mean XT, SW, and SWXT Costs and mean SIMPLE RTs were computed for each subject for the letter and digit tasks separately. These means were entered into four separate 2 × 2 mixed-design ANOVAs with one between-group factor of Group (LM, DM), and one within-group factor of Task Motivation (low-motivated, high-motivated). None of the Group by Task Motivation interactions was significant, indicating no general letter or digit task bias.

Only the SW and SWXT Cost analyses yielded significant main effects for Task Motivation. Specifically, SW Cost was greater for the low-motivated (Cost = 281 ms; 815 vs 534) than high-motivated task (Cost = 209 ms; 728 vs 519), $F(1, 14) = 14.05$, $p < .005$. Similarly, SWXT Cost was greater for the low-motivated (Cost = 420 ms; 954 vs 534) than high-motivated task (Cost = 344 ms; 863 vs 519), $F(1, 14) = 12.33$, $p < .005$. Differences between the low- and high-motivated tasks were similar for both SW (72 ms) and SWXT (76 ms) Costs (Fig. 1).

Task Motivation did not affect XT Cost, $F(1, 14) = .93$, n.s., or SIMPLE RT, $F(1, 14) = 2.31$, n.s. Finally, there was no significant main effect for Group, suggesting that letter- and digit-motivated subjects performed comparably overall.

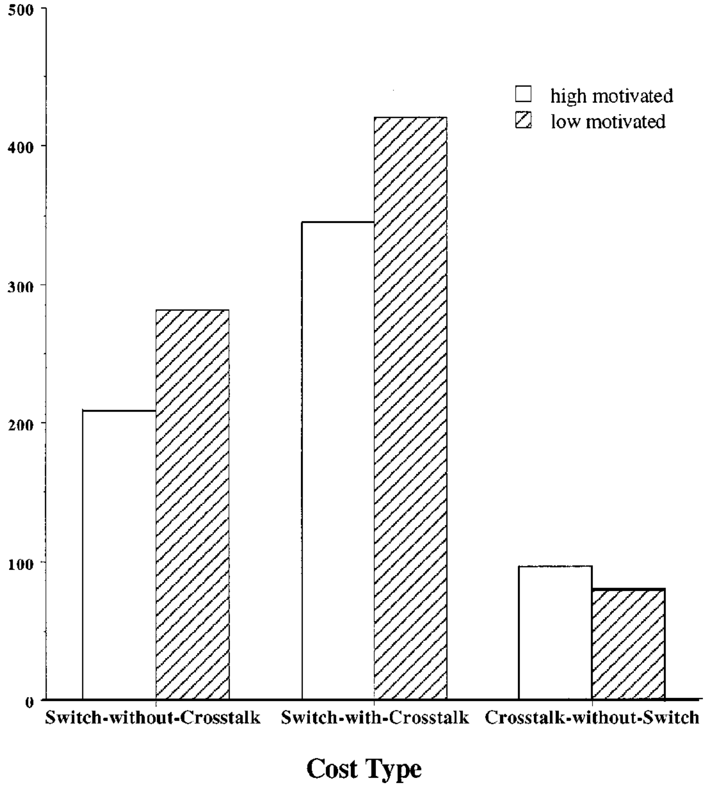

FIG. 1. Mean costs for the high-motivated and low-motivated tasks for each of the three attention indices.

Discussion

Results revealed that task motivation affected attention switching, but not inhibition of crosstalk, nor basic response execution time. This is especially interesting since the incentive bias was manipulated only during training, while equal incentives were present during the subsequent switch task. These results provide further evidence for the distinction between different components of attention (Segalowitz et al., in press). Within this paradigm, switch trials required the intervention of attention control for appropriate resolution of response competition, whereas inhibition of the competing foil on crosstalk trials implicated primarily selective attention to resolve perceptual competition. Interestingly, motivation seems to have affected attentional control of response, but not perceptual competition.

Alternatively, one could argue that predictability, rather than type of attentional mechanism, was responsible for the differential effects of motivation on switch trials (predictable) and crosstalk trials (unpredictable). While the present data cannot speak directly to this confound, the absence of a motivational effect on nonswitch trials makes a predictability explanation less plausible. That is, although both switch and nonswitch trials were equally predictable, a motivational bias obtained for switch trials (815 vs 728 ms) but not nonswitch trials (534 vs 519 ms), suggesting that predictability is not sufficient to account for the pattern of motivational effects found here.

These results invite speculation regarding the neural systems that mediate both motivation and attention switching, pointing to a possible role of dopaminergic influences on the ventral striatum, which prior research has implicated in both incentive motivation and response switching (Dunnett & Robbins, 1992; Rogers et al., 1998).

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