Journal of the International Neuropsychological Society (2006), **12**, 538–548.

DOI: 10.1017/S135561770606070X

Forming, switching, and maintaining mental sets among psychopathic offenders during verbal and nonverbal tasks: Another look at the left-hemisphere activation hypothesis

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(RECEIVED October 17, 2005; FINAL REVISION March 20, 2006; ACCEPTED March 21, 2006)

Abstract

Three hypotheses for cognitive deficits among psychopaths were tested: executive dysfunction, left hemisphere activation, and an interaction between the two. Twenty-one psychopathic and 23 nonpsychopathic criminal offenders identified with the Hare Psychopathy Checklist-Revised participated in verbal and visual-spatial tasks during which the level of executive processing demands was manipulated. Consistent with prior research, psychopathic offenders made more errors than controls, but only during the verbal task and only on trials with high executive demand. Within those trials, most errors occurred when set-maintenance demands were the highest. No response latency differences between groups were found. (*JINS*, 2006, *12*, 538–548.)

Keywords: Response modulation; Laterality; Reaction time; Executive functions; Psychopathic personality; Switching task; Visual-spatial; Attention deficit disorder; Cognition

INTRODUCTION

Psychopathy is a disorder characterized by pervasive antisocial and criminal behavior, impulsivity, disorganization, and failures in planning ahead or formulating appropriate adult goals (Cleckley, 1976). Given these characteristics, it has been proposed that psychopaths may suffer from executive weaknesses (Gorenstein, 1982), and a number of studies have in fact found that individuals with psychopathic characteristics perform more poorly than controls on tasks requiring behavioral control (Lapierre et al., 1995) or response modulation (RM) under competing contingencies (Fisher & Blair, 1998; Lapierre et al., 1995; Morgan & Lilienfeld, 2000; Newman & Schmitt, 1998; Smith et al., 1992). However, findings in this area have been inconsistent (Hare, 1984; Hart et al., 1990).

This article is a replication and extension of our previous study that was published in the *JINS*, volume 11, 2005. The article appeared as "State-dependent Executive Deficits Among Psychopathic Offenders," by Suchy & Kosson, 2005, *JINS*, 11:3, pp. 311–321. There was no overlap in participants between the two studies.

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One explanation for inconsistent findings is offered by the left-hemisphere activation (LHA) hypothesis (Kosson, 1996, 1998), which states that psychopaths' deficits in cognitive processing are state-specific, occurring primarily when the left cerebral hemisphere is activated substantially more than the right hemisphere. This hypothesis does *not* imply a *specific* deficit in cognitive abilities associated with left-hemisphere processing. Rather, the LHA hypothesis predicts that information processing in *general* (i.e., *all* cognitive abilities, *including executive* abilities) will be disrupted among psychopaths when left-hemisphere systems are substantially and differentially activated by processing demands (Kosson, 1998). When the left hemisphere is activated less than, or as much as, the right hemisphere, no deficits should occur. Although the LHA hypothesis has been corroborated by several studies (Kosson, 1998; Suchy & Kosson, 2005), some inconsistencies in findings remain, casting doubt on its original, or *general*, version. Instead, an *interaction* between LHA and emerging executive weaknesses (LHA × EW) may present a more viable explanation for prior findings.

First, prior investigations of the LHA hypothesis yielded somewhat different patterns of results, demonstrating deficits on some, but not all, task components. Although such findings may simply reflect differential discriminating power of different tasks, they may also reflect differential executive demands of individual task components. In other words, deficits under LHA conditions may only be found when tasks tax the executive system.

Second, direct examinations of the LHA hypothesis have generally relied on paradigms in which differential hemispheric activation was achieved by manipulating primarily attentional and motor resources, such as, for example, presenting stimuli into the right *versus* left visual field and requiring primarily right- *versus* left-handed responses. However, given the well-understood relationship between verbal processing and the left hemisphere (Lezak, 1995), sustained engagement in a verbal task would also be expected to differentially activate the left-hemisphere, and as such should lead to an impairment on the verbal task itself. Yet, this has not been found, with the exception of higher-order abstract verbal classifications (Hare & Jutai, 1988).

Third, we recently tested three competing hypotheses of deficits among psychopaths (LHA, EW, and LHA × EW)[1] and found support for the LHA × EW interaction (Suchy & Kosson, 2005), with psychopaths making substantially more response modulation (i.e., executive) errors than nonpsychopaths, but only during LHA.[2] However, in addition to these errors, a mild slowing across the board was also found under LHA, suggesting that LHA may have affected general processing as well (i.e., beyond executive). Unfortunately, because of the complexity of our design, some executive demands were placed on participants during each trial, precluding conclusive separation of LHA from LHA × EW.

The purposes of this study were two-fold. First, we aimed to examine the robustness of the previously found LHA × EW interaction, while using a less complex design that would allow clearer separation of "executive" and "nonexecutive" task components. Second, because most prior studies of LHA relied on manipulation of attention and action to increase left-hemisphere processing, we aimed to test the effects of LHA by manipulating higher-order cognitive demands.

To these ends, we used two tasks designed to differentially tax hemispheric resources. To tax the left hemisphere, we designed a verbal task (VT) consisting of concrete word classifications, an activity known to rely primarily on left-hemisphere resources (Binder et al., 2005; Fiebach & Friederici, 2004; Khateb et al., 2003; Kiehl et al., 1999; Taylor et al., 1999; Warrington et al., 1998; Yano et al., 2000). To tax the right hemisphere, we designed a nonverbal task (N-VT) consisting of abstract design classification, an activity known to rely primarily on the right hemisphere (Basile et al., 1997; Kato et al., 2001).[3] Each task included periodic increases in executive demands including the need to form, switch, or maintain mental set (Osmon, 1999; Osmon & Suchy, 1996).

As in our previous study (Suchy & Kosson, 2005), we tested three competing hypotheses: (1) the LHA hypothesis, predicting that engagement in VT would affect psychopaths' *general* information processing, with no such effect being observed during N-VT; (2) the EW hypothesis, predicting that psychopaths would exhibit *executive* problems on both tasks (i.e., VT and N-VT); and (3) the LHA × EW interaction, predicting that psychopaths' would exhibit executive and only executive deficits, but only during the VT.

METHOD

Participants

Participants were 44 male inmates recruited from the Lake County Jail in Waukegan, Illinois. Selection of participants consisted of a two-step process. First, interested male inmates (18 to 45 years old, convicted of a felony or misdemeanor, English speakers, free of psychotropic medication or medication with known neurocognitive side-effects, and free of overtly psychotic, bizarre, or dangerous behaviors) participated in an extensive assessment of psychopathy (using Psychopathy Checklist-Revised; PCL-R), substance abuse, handedness, anxiety, and intelligence.

Second, participants were included in the study if they (a) had a PCL-R total score of 30 or above (classified as psychopathic: P) or 20 or below (classified as nonpsychopathic: NP),[4] (b) had a Full Scale IQ estimate of 80 or higher to ensure adequate intellectual capacity for task performance, (c) were right-handed, (d) denied difficulty perceiving colors, (e) were either European American (EA) or African American (AA), so as to allow examination of ethnicity effects, (f) completed at least two thirds of all trials correctly (50% indicates chance performance), (g) performed within two standard deviations of group means on performance indices, and (h) had a complete set of behavioral data. See *Instruments* for further description.

This two-step selection process resulted in 23 P and 21 NP participants (see Table 1). P and NP groups did *not*

[1]In our previous manuscript (Suchy & Kosson, 2005), we used the term "response modulation" (RM), in line with the terminology commonly used in psychopathy studies that test responsiveness to two competing contingencies. However, situations that pose competing contingencies and require that a choice be made necessarily tax the executive system. In other words, RM difficulties represent one specific type of executive weakness. Thus, in our present study, we moved to using the phrase "executive weakness," as it is in line with (a) the nomenclature used in neuropsychology, (b) the neurocognitive demands posed by the present study, and (c) our theoretically-based intention to test several specific aspects of executive functioning.

[2]This finding was also consistent with one other study that suggested an interaction between executive processing and LHA (Bernstein et al., 2000).

[3]It should be noted that neither the LHA hypothesis, nor our present design, presupposes that *only* one or the other hemisphere would be activated at any given time. Rather, differential hemispheric activation in which the left hemisphere is simply more engaged than the right is all that is required for the LHA condition. Similarly, a task in which the left hemisphere is *not* more activated than the right hemisphere is all that is required for the non-LHA condition.

[4]This procedure is well recognized in the psychopathy literature and follows the recommendations of the PCL-R manual.

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Table 1. Demographic characteristics of the sample

	Psychopaths ($n = 23$)	Nonpsychopaths ($n = 21$)
Age (years)	26.96 (7.13)	24.90 (6.69)
Education (years)	11.43 (1.92)	11.76 (1.30)
FSIQ estimate	96.35 (9.93)	96.24 (6.25)
WAI	15.44 (9.34) [$n = 18$]	6.78 (4.47) [$n = 18$]
Percent AA	52.20	38.10
Percent ETOH abuse	23.50 [$n = 17$]	30.00 [$n = 20$]
Percent ETOH dependence	52.90 [$n = 17$]	40.00 [$n = 20$]
Percent drug abuse	5.9 [$n = 17$]	30.00 [$n = 20$]
Percent drug dependence	76.5 [$n = 17$]	50.00 [$n = 20$]

Note. Standard Deviations are presented in parentheses. Substance use and anxiety assessment data were not available on all participants.
AA = African American; FSIQ = Full Scale IQ estimate based on Shipley Institute of Living Scale; WAI = Welsh Anxiety Scale; ETOH = alcohol.

differ in FSIQ estimate, age, education, ethnicity distribution, or substance use. However, P participants scored higher on Welsh Anxiety Inventory (WAI), $t\,(34) = 3.55$, $p = .001$, consistent with several recent studies (Hale et al., 2004; Suchy & Kosson, 2005; Sutton & Davidson, 1997).[5]

Instruments

Psychopathy checklist-revised

The PCL-R is the instrument of choice for assessing psychopathy (Hare et al., 1991). The PCL-R is a 20-item rating scale shown to have excellent reliability and validity. Items address prominent characteristics of psychopathy, such as callousness, irresponsibility, sexual promiscuity, and criminal versatility. The PCL-R was completed based on information obtained from available legal records combined with detailed interviews with inmates.

Shipley Institute of Living Scale-revised

The Shipley Institute of Living Scale (SILS, Zachary, 1986) was used to estimate intelligence. It consists of 40 vocabulary items and 20 analytical reasoning items, and contains normative tables for converting performances into Wechsler Adult Intelligence Scale–Revised (WAIS-R) Full Scale IQ estimates.

Handedness questionnaire

This questionnaire (Chapman & Chapman, 1987) consists of 13 handedness questions.

Welsh anxiety inventory

The WAI (Welsh, 1956) is a self-report measure of trait anxiety widely used in psychopathy studies (Newman et al., 1987; Schmitt & Newman, 1999). Scores are commonly interpreted as reflecting trait negative affectivity (Watson & Clark, 1984).

Experimental Tasks

Two classification tasks were administered: a VT, designed to activate left-hemisphere processing, and a N-VT, designed to activate right-hemisphere processing. Tasks were designed to contain (a) high executive-demand (HED) trials, and (b) low executive-demand (LED), or "control," trials. All instructions, cues, stimuli, and feedback were presented *via* computer screen.

Verbal task

The VT presented concrete words, one at a time. On each trial, participants were asked to respond "yes" (an *index* finger press on a designated computer keyboard key) or "no" (a *middle* finger press on a designated key) regarding one of the following classifications: (a) Does this word represent an animal? or (b) Does this word represent something found on a typical Midwestern farm? Some words belonged to either both categories (e.g., "cow") or neither category (e.g., "church") and as such were designated as "congruent"; other words belonged to only one category (e.g., "rake" or "tiger") and as such were designated as "incongruent." Participants classified words according to the cues presented on the computer screen (i.e., "Animal?" or "On the farm?"), and received feedback regarding the speed and accuracy of their performance. Specifically, responses faster than 450 ms (representing approximately the 5th percentile, based on pilot data) were followed by the words "Speed bonus," responses slower than 1200 ms (representing approximately the 95th percentile, based on pilot data) were followed by the words "Too slow," and incorrect responses were followed by error feedback (the word "Wrong," accompanied by a cue regarding the currently correct classification principle). To ensure that all partici-

[5]WAI and substance use information was not available for all participants.

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pants, regardless of their cultural background, understood what items are associated with a Midwestern farm, a list of all the words used in the study associated with this category was provided during instructions.

Non-verbal task

The N-VT presented abstract designs, two at a time. On each trial, participants were asked to respond either "yes" (an *index* finger press) or "no" (a *middle* finger press) regarding one of the following classifications: (a) Do the two designs match in color? or (b) Do the two designs match in shape? Whereas some designs either matched or did not match in both color and shape and as such were designated as "congruent," others matched in either only color or only shape and as such were designated as "incongruent." Participants were instructed to classify designs according to the category that was indicated to them *via* cues ("Same color?" and "Same shape?"). To minimize verbalization, the stimuli were designed to be highly abstract and "nonsensical," and the coloring of each design consisted of nonprimary colors and/or mixtures of shades and hues. As was the case in the VT, feedback regarding speed and accuracy was provided.

High Executive-demand Trials

Both the VT and the N-VT were designed to instantiate 3 types of executive demands: forming, switching, and maintaining mental set. Increases in executive demands were accomplished by: (a) presenting cues indicating the classification principle to be used in the subsequent block of trials, loosely based on the so-called switching task paradigm (Allport et al., 1994; Jersild, 1927), and (b) arranging the sequence in which trials occurred, based loosely on the Wisconsin Card Sorting Test (Heaton et al., 1993) and on principles employed in various continuous performance tasks (Connors, 2000). These manipulations are described later.

First, to manipulate set switching and set forming demands, approximately every eight trials a cue was presented signaling which classification principle should be observed next. This principle was valid until the next cue appeared. Each new cue could be either different from the previous cue, indicating a change in the classification principle, or the same as the previous cue, indicating that the classification principle should remain unchanged. When a cue indicated a change, participants needed to switch to the new principle on the immediately following trial; these cues were referred to as "Switch cues." When a cue did *not* indicate a change, participants simply needed to "reconsider" (Gopher et al., 2000) their current response set, ascertaining that their set and the cue matched and that no switching was required; these cues were referred to as "Form cues."

Trials immediately following Switch and Form cues are known to be associated with increased processing demands, reflected in longer response latencies (Allport et al., 1994; Gopher et al., 2000; Jersild, 1927). Because of the top-down requirements of responding to cues under these conditions, the additional processing demand is believed to represent an index of executive control (Mecklinger et al., 1999; Rogers et al., 1998). This notion is corroborated by experimental studies conducted with normal participants (Gopher et al., 2000; Lorist et al., 2000; Monsell et al., 2000) and with individuals known to demonstrate weaknesses in executive abilities (Cepeda et al., 2001; Kramer et al., 1999; Kray et al., 2002; Kray & Lindenberger, 2000; Salthouse et al., 1998).

In this study, trials immediately following Switch and Form cues were referred to as "Switch trials" and "Form trials," respectively. All Switch and Form trials were incongruent, as were all trials immediately preceding Switch or Form cues. See Figure 1 for a sample trial sequence.

Second, to increase set-maintenance demands, trial sequences were manipulated such that, some of the time, a series of approximately eight *congruent* trials was followed by an *incongruent* trial. As a reminder, each *incongruent* trial has *two* different potentially correct responses (one for each classification principle), whereas each *congruent* trial has only *one* potentially correct response (regardless of the current classification principle). This difference in the number of possible responses has important implications for set-maintenance demands. In particular, when performing a series of *incongruent* trials, the need to select from among two potential responses continually forces participants to refresh their mental sets regarding the current classification principle. In contrast, when performing a series of only *congruent* trials, nothing about the stimuli reminds participants to refresh their mental sets regarding the classification principle (because the response is the same regardless). Thus, participants need to *self-cue* to maintain mental set and to avoid allowing the congruent nature of these trials to

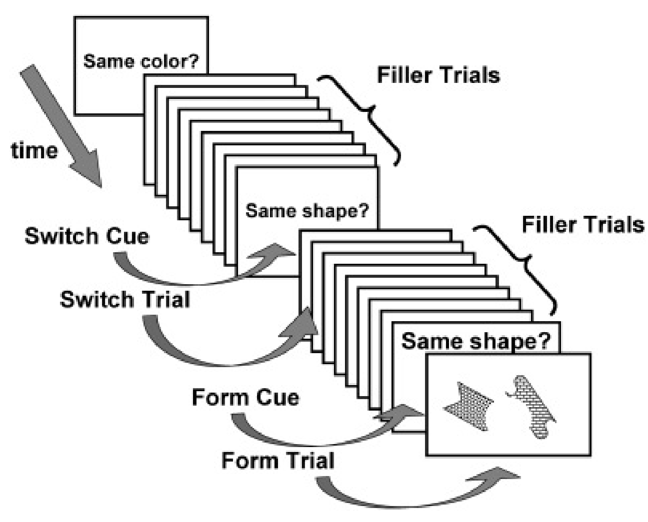

Fig. 1. Sample sequence of trials, showing form, switch, and filler trials.

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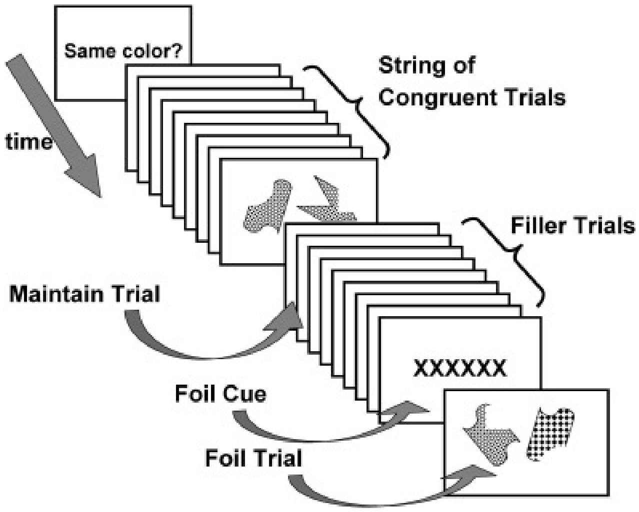

Fig. 2. Sample sequence of trials, showing foil, set-maintenance, and filler trials.

lull them into inattentiveness.[6] In a recent study, participants with mixed features of inattentiveness and impulsivity responded more impulsively on maintenance trials than participants without such symptoms (Suchy et al., 2003).

In the present study, the trials of interest (referred to as "Maintenance trials") were the *first incongruent trials* immediately following a series of congruent trials. See Figure 2 for a sample trial sequence.

Low Executive-demand Trials

Trials placing fewer demands on executive systems were designed to be comparable to HED trials, but without requiring participants to form, switch, or maintain mental sets. First, to present LED trials identical to Switch and Form trials in every regard except the need to switch or form set, Switch and Form cues were periodically replaced with a cue foil that presented no task-relevant information and consisted of a series of six Xs. Participants were instructed to ignore these foils and proceed with the task. The trials immediately following these foils were referred to as "Foil trials." See Figure 2 for a sample trial sequence.

Second, to present LED trials comparable to Maintenance trials, we used the series of incongruent trials that occurred between cues (excluding Switch, Form, and Foil trials). These trials were referred to as "Filler trials." Filler trials were similar to Maintenance trials in that they were incongruent and were *not* preceded by a cue, but they were *not* preceded by a series of congruent trials, and as such did not require the same demands for self-cued set-maintenance. See Figures 1 and 2 for examples of filler trials.

[6]Readers familiar with clinical assessments using the WCST may notice that our design is reminiscent of the occasional series of "congruent" cards that sometimes precipitate failures to maintain set.

Task Parameters

Each task consisted of 351 trials (169 congruent and 182 incongruent) with the total of 24 stimuli presented in random order (only incongruent trials were used in analyses). There were eight each of form, switch, maintenance, and foil trials, and 150 filler trials. The order of manipulations was randomized for each participant.

Verbal stimuli were approximately one inch tall. Visual-spatial stimuli were approximately five inches tall and three inches wide. Each stimulus remained on the screen until a participant responded. Response-stimulus interval was 20 ms. Cues and feedback were presented on the screen for 750 ms, followed by a 20 ms interval.

Procedures

Eligible inmates who participated in screening and interview procedures (described in *Participants*) were re-contacted on a separate day by an examiner blind to their psychopathy ratings, and invited to participate in behavioral testing conducted individually in a small program room at the jail. All participants underwent IRB-approved informed consent procedures, separately for screening and testing.

The VT and N-VT were counterbalanced and were preceded by 12 practice trials. Participants were given the option to repeat practice trials if they felt they did not fully understand how to perform the task. Task stimuli were presented on a Gateway XP laptop computer with a 14 inch computer screen. Participants responded by pressing designated keys on a computer key board using their index and middle fingers. Response latency and number of errors were recorded.

To encourage fast and accurate responding and to discourage speed-accuracy trade-offs, participants were informed that they would earn one cent for each "speed bonus" feedback and lose one cent for each "wrong" or "too slow" feedback. Participants were paid eight dollars for participation plus their earnings.

Testing sessions lasted approximately 90 minutes and included other behavioral tasks presented after the current tasks, unrelated to the present study. Breaks were provided after each behavioral task.

RESULTS

To test all three hypotheses simultaneously, we first computed the percent error and median response latency for each participant, separately for Form, Switch, Maintenance, Filler, and Foil trials. Next, we generated arithmetical means of the above values so as to create the following composite scores: (1) Verbal task, high executive demand (VT-HED), consisting of all the VT Form, Switch, and Maintenance scores, (2) Non-verbal task, high executive demand (N-VT-HED), consisting of all the N-VT Form, Switch, and Maintenance scores, (3) Verbal task, low executive demand (VT-LED), consisting of all the VT Foil and Filler scores,

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Table 2. Means and standard deviations (in parentheses) for response latencies for high and low demand trials of the verbal and nonverbal tasks

	Task		Task difficulty effect size
Executive demand level	Verbal	Nonverbal	Cohen's *d*
High	726.07 (93.57)	722.78 (86.05)	.04
Low	703.83 (103.69)	687.70 (81.85)	.16
Executive Demand Effect Size (Cohen's *d*)	.34*	.65**	

Note. *$p <. 05$, **$p < .01$. $N = 44$.

(4) N-VT, low executive demand (N-VT-LED), consisting of all the N-VT Foil and Filler scores.

Preliminary Analyses

To test the effectiveness of our executive-demand manipulation (i.e., the expectation that HED trials would be associated with longer response latencies compared to LED trials), we conducted paired *t*-tests comparing response latencies of LED and HED trials, separately for VT and N-VT. The results showed that, as expected, responses to HED trials were reliably slower than those to LED trials, both for VT [t (43) = 2.26, p = .029], and for N-VT [t (43) = 4.25, p < .001]. See Table 2.

To compare the difficulty of the two tasks, we conducted paired *t*-tests comparing VT and N-VT response latencies, finding no differences for HED or LED trials (both *t* values <1; see Table 2).

Based on common practice, we explored the need to control for the effects of age, education, IQ estimate, and anxiety. Additionally, because of questions regarding the validity of the PCL-R with AA participants (Cooke et al., 2001; Toldson, 2002), and because AA psychopaths sometimes fail to show the same cognitive deficits as those exhibited by EA psychopaths (Lorenz & Newman, 2002), we explored the need to include ethnicity as an additional factor. To that end, we correlated these variables with the principal dependent variable, finding support for the use of education and IQ estimate as covariates, and ethnicity as an additional factor (Table 3). Because of statistical complications (discussed later), we addressed anxiety as a covariate in the Supplementary Analyses section.

Principal Analyses

To test all three hypotheses simultaneously, we conducted two repeated measures analyses of covariance (ANCOVAs), one each for accuracy and response latency, using Task (VT vs. N-VT) and executive demand level (HED *vs*. LED) as within-subjects factors, and offender group (P *vs*. NP) as a between-subjects factor. Additionally, based on preliminary analyses (Table 3), we used education and estimated IQ as covariates, and ethnicity (AA *vs*. EA) as an additional between-subjects factor. We followed up with univariate analyses, using the same factors and covariates, designed to further explicate findings. There were no sig-

Table 3. Correlation coefficients for relationship between performance variables and potential covariates

Dependent variables			Covariates				Factor
Measured entity	Task	Executive demand	Age	Education	IQ estimate	Anxiety	Ethnicity
Resp Lat	Verbal	High	.006	−.425**	−.376*	.103	−.255
		Low	−.063	−.472**	−.290	.168	−.315*
	Nonverbal	High	.145	−.172	−.429**	.024	−.228
		Low	.032	−.229	−.272	.043	−.138
Percent Error	Verbal	High	.045	−.007	−.151	.317	−.132
		Low	.069	−.149	−.403*	.162	−.189
	Nonverbal	High	.020	−.102	−.332*	−.134	−.053
		Low	−.138	.011	−.198	−.377*	.044

Note. *$p < .05$, **$p < .01$. $N = 44$.
Ethnicity coding: 1 = African American, 2 = Caucasian. Resp Lat = Response Latency; Anxiety was assessed using the Welsh Anxiety Inventory (higher scores represent higher levels of anxiety).

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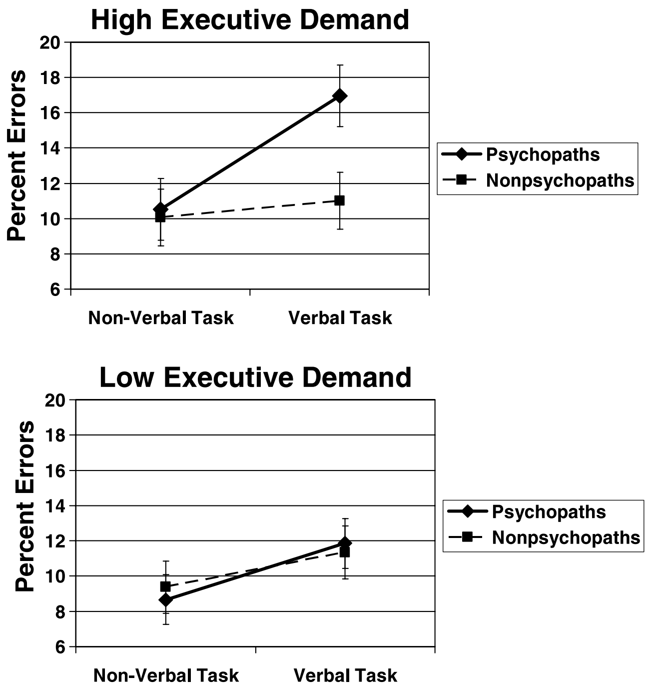

Fig. 3. Interaction between Task (i.e., left hemisphere *vs.* right hemisphere activity), Level (i.e., high *vs.* low executive demand) and Group membership (i.e., psychopaths *vs.* nonpsychopaths). As can be seen, psychopaths exhibited a greater error rate than nonpsychopaths during high executive demand trials during the left hemisphere activity.

nificant main effects or interactions involving education or ethnicity.[7] There was a main effect of estimated IQ on accuracy [$F(1,39) = 8.19$, $p = .007$].

Response Accuracy

Analyses yielded an interaction between executive demand level and offender group [$F(1,39) = 5.11$, $p = .030$], as well as a three-way interaction trend among task, executive demand level, and offender group [$F(1,39) = 3.64$, $p = .064$]. Consistent with the LHA × EW hypothesis, follow-up univariate analyses revealed that P participants made more errors than NP participants *only* during the HED trials of the VT [$F(1,39) = 4.86$, $p = .034$], with no difference found for the N-VT ($F < 1$), and no differences found for LED trials (Fs < 1). See Figure 3 for an illustration of this interaction.

To examine whether individual components of the HED and LED processes were driving this effect, we conducted univariate analyses of covariance (ANCOVAs) separately for form, switch, maintain, filler, and foil trials, again controlling for education and IQ estimate and using offender group and ethnicity as a between-subjects factors. These analyses yielded a reliable difference between P and NP participants only for the trials assessing the ability to maintain mental set, and only during the VT [$F(1,39) = 7.69$, $p = .008$]. See Table 4 for estimated marginal means and standard error data.

Response Latency

There were no reliable group differences (main effects or interactions) for response latencies, whether for the composite scores or for individual scores.

Supplementary Analyses

Effects of anxiety

For logistical reasons, WAI was not available on six participants, which reduced the sample size from the original 44 to 38. As an additional complication, offender groups differed on WAI, making anxiety a problematic covariate (Miller & Chapman, 2001).

To partially remedy this problem, we removed an additional 6 P individuals whose anxiety scores were the highest and were outside of the range of the NP group, essentially "matching" the groups on anxiety (the resulting sample had 12 P and 18 NP participants). This procedure eliminated the significant group difference on WAI [t (28) = 1.85, $p = .075$].

Because of the considerable decrease in power associated with a decrease in sample size, and the fact that the present analysis was intended to confirm and replicate a specific unidirectional finding, we relied on unidirectional probabilities when conducting this analysis. Analyses yielded the same pattern of results, with a three-way interaction for response accuracy among task, executive demand level, and offender group [$F(1,24) = 3.89$, $p = .030$], and no significant main effects or interactions for response latency. Also, the P group again performed more poorly only on HED trials and only during VT [$F(1,24) = 3.60$, $p = .035$], which appeared to be mainly caused by poorer performance on the maintenance trials [$F(1,24) = 4.60$, $p = .021$].

DISCUSSION

The present study compared three competing hypotheses of cognitive processing deficits among P criminal offenders: (1) the LHA hypothesis, (2) the EW hypothesis, and (3) the interaction between the two (LHA × EW). The present findings are consistent with previous research (Bernstein et al., 2000; Suchy & Kosson, 2005), providing corroboration for the LHA × EW interaction. P criminal offenders made more

[7]While examination of ethnicity was not the primary focus of the present study, the fact that the results were not affected by ethnicity provides indirect support for the use of the PCL-R with both ethnic groups, consistent with Cooke et al. (2001). Additionally, because ethnicity only correlated with LHA-LED response latency, and because education also correlated with this variable (Table 3), it is possible that the apparent relationship between performance and ethnicity was due to shared variance with education. To examine this possibility, we computed the partial correlation between ethnicity and LHA-LED, controlling for education. After controlling for education, ethnicity was no longer related to task performance [patial $r = .246$, $p = .113$]. This may explain why ethnicity had no significant main effects or interactions in principal analyses, despite the significant correlation presented in Table 3.

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Table 4. Estimated marginal means and standard errors of the mean (in parentheses) for percent error results for left and right hemisphere activities

Trial type			Percent errors per trial type		Effect size
Task	Level	Trial	Psychopaths ($n = 23$)	Nonpsychopaths ($n = 21$)	Cohen's d
VT	HED		16.97 (1.85)	11.00 (1.96)	.47*
		Form	9.32 (2.64)	6.77 (2.81)	.13
		Switch	14.10 (2.52)	10.66 (2.68)	.19
		Maintain	27.49 (2.93)	15.55 (3.12)	.61**
VT	LED		11.35 (1.28)	11.83 (1.37)	<.10
		Foil	9.37 (1.95)	8.58 (2.08)	<.10
		Filler	13.32 (1.61)	15.08 (1.71)	−.16
N-VT	HED		9.51 (1.46)	9.06 (1.56)	<.10
		Form	5.02 (1.75)	3.33 (1.86)	.13
		Switch	10.25 (2.73)	11.31 (2.90)	<.10
		Maintain	13.27 (2.36)	12.55 (2.51)	<.10
N-VT	LED		8.67 (1.36)	9.37 (1.45)	<.10
		Foil	7.76 (2.21)	7.35 (2.35)	<.10
		Filler	9.59 (1.32)	11.40 (1.40)	−.22

Note. VT = Verbal Task, N-VT = Non-Verbal Task; HED = High Executive Demand, LED = Low Executive Demand. *$p < .05$, **$p < .01$

errors than NP offenders, but only during VT, and only during trials that placed high demands on executive processing. In addition, the present study extends prior findings in two regards: First, it addresses methodological issues that limited interpretation in previous research; and second, it points to a possible specific deficit in set maintenance.

Methodological Issues

Left hemisphere activation and linguistic processing

First, the present study addressed an important issue overlooked in prior LHA studies, namely the fact that the original, or general, version of the LHA hypothesis (stating that information processing on all task components should be deleteriously affected when the left cerebral hemisphere is substantially and differentially activated) should lead to deficits on demanding linguistic tasks. From this general perspective, a failure to find deficits on demanding linguistic tasks should be viewed as evidence *against* the LHA hypothesis. On the other hand, a more specific version of the LHA hypothesis, namely the LHA × EW interaction, allows for normal linguistic processing in the presence of a circumscribed deficit in executive processing. By examining simultaneously both linguistic processing and executive processes, we demonstrated that P participants exhibited executive deficits while successfully engaging in a linguistic task. A failure to find general group differences on the linguistic portion of the task is consistent with prior research (Hare & Jutai, 1988).

General performance slowing as a function of specific executive difficulties

By designing our present study in such a way so as to completely separate LED and HED trials, we were able to address a question that was raised, but not fully answered, in our previous study (Suchy & Kosson, 2005). In that study, two auditory stimuli were presented during each trial. Participants had to attend to the overall pitch of each stimulus to determine whether it represented a target, and then classify targets according to their tonal contours. Our results had shown that P participants made more commission errors (i.e., responding to non-targets as though they were targets) in the LHA condition, consistent with the LHA × EW hypothesis. However, P participants had also exhibited overall slowing under the LHA conditions, consistent with the general LHA hypothesis. Unfortunately, we were not able to determine whether this slowing was caused by the LHA manipulation, or whether it was secondary to over-responding to distractors.

The present study addressed the above question by fully separating LED and HED trials. Given that the present study yielded a group difference only on the VT and only for HED trials, with no effect for LED trials (Cohen's $d < .19$), it appears likely that the slowing observed in our previous study was secondary to executive difficulties.

Deficit in set maintenance

Consistent with previous research (Bernstein et al., 2000; Suchy & Kosson, 2005), the present findings corroborate the LHA × EW hypothesis, suggesting that LHA affects

https://doi.org/10.1017/S135561770606070X Published online by Cambridge University Press

processing of task components that have high executive demands. However, the present study further suggests a *specific* executive difficulty: as can be seen from the effect sizes in Table 4, the apparent overall effect of LHA on HED processes seems almost entirely driven by the maintain score. In particular, across the tasks' eight maintenance trials, P participants made approximately two errors, whereas NP participants made approximately one error. This difference may translate into a considerable difference in daily functioning when extrapolated across the high number of situations requiring set maintenance in a person's day. This group difference is consistent with a variety of prior research on cognitive processing among P offenders, particularly when the nature of the maintain score is considered.

Set maintenance and response modulation

First, as much RM research suggests, executive deficits among psychopaths are particularly prominent when self-monitoring and self-cuing are required (Newman et al., 1987; Newman & Schmitt, 1998). In particular, P offenders fail to self-cue to attend to so-called "secondary" task characteristics (such as, for example, attending to stimulus dimensions that allow differentiation of targets from non targets). Similarly, in the present study, when classifications surreptitiously became easier, P participants seemed to fail to self-cue to stay on task.

Set maintenance and over-focusing

Second, the present findings are consistent with an older hypothesis known as "over-focusing" (Jutai & Hare, 1983; Kosson & Newman, 1986, 1989), which suggested that P participants over-focus on immediate goals, to the exclusion of other stimuli or goals. Although several studies have contradicted the strong form of this hypothesis (e.g., Kosson, 1996, 1998), psychopaths seem to experience less interference than other offenders in some Stroop-like situations (Vitale et al., 2005). Thus, P participants seem to process the minimal amount of information necessary for a task at hand. Similarly, in our study, psychopaths failed to engage in the extra processing needed for set maintenance during congruent trials.

Set maintenance and the right hemisphere

Third, in our previous study (Suchy & Kosson, 2005) we found indirect support for the suggestion that one of the mechanisms driving the LHA effect might be excessive inhibition of the right hemisphere. The presently observed difficulties with set maintenance are consistent with this interpretation, given that right-hemisphere is considered dominant for attention and vigilance (Bearden et al., 2004; Erickson et al., 2005; Saletu et al., 2005) and possibly implicated in attention deficit disorder (Casey et al., 1997; Corbett & Glidden, 2000; Garcia-Sanchez et al., 1997; Overmeyer et al., 2001).

Clinical Implications

Behavioral control among psychopaths is known to vary from one situation to the next (Cleckley, 1976). Because left hemisphere systems are activated during highly rewarding states (Thut et al., 1997), psychopaths who find themselves in the presence of highly desired objects or goals may experience LHA, which leads to a break-down of executive control and diminishes their capacity for self-cueing and following through with less-desired goals, such as parole requirements.

Limitations

Several aspects of the present study limit interpretation of the results. First, whereas form and switch components of the present study are based on a classic paradigm (Allport et al., 1994; Jersild, 1927), the maintain component has been validated by only one previous study using impulsive and inattentive college students (Suchy et al., 2003). Examinations of the present paradigm with additional populations are needed to further validate the construct assessed by these trials.

Second, participants in the present study received feedback (and concrete rewards and punishments) regarding their performance. It is not clear whether similar findings would result if rewards or punishments were not presented. This issue should be examined in future studies.

Third, P participants in the present sample tended to score higher on anxiety than their NP counterparts. Although we partially addressed this issue statistically by removing some of the P participants with extremely high scores, a better understanding of the effects of anxiety will require larger samples that can be meaningfully separated into high and low anxious groups.

Fourth, because of logistical limitations, we did not screen participants for neurologic or psychiatric disorders except for psychosis or aggression. Although such information might be informative, the results still demonstrate differences between groups that are theoretically consistent.

ACKNOWLEDGMENTS

The authors thank Charles de Filippo, Patrick Firman, and the staff of the Lake County Jail in Waukegan, Illinois for their consistent cooperation and support during the conduct of this research; also Lindsay Allen, Amy Bagley, Elizabeth Sullivan, Marc Swogger, Linda Thede, and Zachary Walsh for interviewing the inmates and administering the experimental task. The research and preparation of this article were supported in part by Grants MH49111 and MH57714 from the National Institute of Mental Health to David S. Kosson. The study was approved by IRB.

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