Interhemispheric Integration in Psychopathic Offenders

Mabel Lopez and David S. Kosson
Rosalind Franklin University of Medicine and Science

Daniel H. Weissman
Duke University

Marie T. Banich
University of Colorado, Boulder

The goal of the present study was to determine whether a reduced capacity for interhemispheric integration can explain the attention deficits seen in psychopathic individuals under conditions that place substantial demands on left-hemisphere–specific resources. The present study examined the performance of 54 incarcerated psychopathic and nonpsychopathic male offenders on a same–different global–local paradigm that permits manipulation of both the magnitude of processing demands and the demand for interhemispheric coordination. Prior studies with similar paradigms have demonstrated that the cerebral hemispheres can function more efficiently as relatively independent processors on simple tasks, whereas communication between the hemispheres improves performance when processing demands are heavy. Analyses indicated that psychopathic offenders are not deficient in interhemispheric integration but provided additional evidence consistent with the left hemisphere activation hypothesis of psychopathy.

Although clinical descriptions of psychopathic individuals often emphasize emotional pathology and suggest that cognitive function is largely intact (Cleckley, 1941), neuropsychological theories suggest that psychopathic individuals exhibit subtle abnormalities in attentional function and/or laterality (Hare, 1991). Traditional neuropsychological measures have generally demonstrated no differences in cognitive processes between psychopathic and nonpsychopathic individuals (Hart, Forth, & Hare, 1990; Smith, Arnett, & Newman, 1992). However, several recent studies document attention deficits in psychopathic individuals in divided attention conditions that place transient heavy demands on left hemisphere processing systems (Kosson, 1996, 1998). For example, in a divided visual field study, Kosson (1998) reported deficits in a condition in which the majority of targets were presented to the right visual field (RVF) and required right-handed responses. Because these conditions were designed to place differential demands on left-hemisphere motor and attentional systems (Lempert & Kinsbourne, 1982; Rizzolatti & Craighero, 1998; Robertson & North, 1992, 1993), this condition was referred to as a left-hemisphere activation (LHA) condition. Under these conditions, psychopathic participants exhibited a deficit in classifying both RVF and left visual field (LVF) targets, suggesting the possibility that they exhibit general deficits under conditions inducing LHA. In contrast, when the majority of targets appeared in the LVF and required primarily left-handed responses (a right hemisphere activation [RHA] condition), and in an equal activation condition, psychopathic participants classified targets as well as did nonpsychopathic individuals.

Converging evidence for a deficit under conditions that induce relative LHA was provided by Suchy and Kosson (2005), who demonstrated significant deficits for psychopathic offenders in dichotic listening that were also specific to conditions designed to require more resources from the left hemisphere than from the right hemisphere. In this study, participants listened to simultaneous sequences of four tones in each ear under conditions in which most target sequences were presented to either the right ear (a LHA condition) or the left ear (an RHA condition). As in Kosson (1998), participants classified right perceptual field targets (here, right ear target sequences) with the right hand and left perceptual field targets (here, left ear target sequences) with the left hand. Additionally, as in Kosson (1998), psychopathic individuals displayed poorer divided attention than did nonpsychopathic individuals only in the LHA condition. More recently, Llanes and Kosson (2006) replicated deficits in LHA conditions in a divided visual field paradigm.

Because all of these divided attention paradigms presented stimuli to both cerebral hemispheres, an alternative explanation for these performance deficits is a reduced capacity for interhemispheric integration, which precludes an effective distribution of processing across both cerebral hemispheres when demands on left-hemisphere processing resources are relatively high. An interhemispheric integration deficit provides a possible explanation for why psychopathic individuals in Kosson (1998), under LHA conditions, were less accurate than those without psychopathy in...
classifying LVF targets as well as RVF targets (see also Kosson, 1996). The possibility of deficient interhemispheric integration in psychopathy is also consistent with links between callosal dysfunction and deficits in affective functioning (Paul, Van Lancker-Siditis, Schieffer, Dietrich, & Brown, 2003) similar to those reported in psychopathic offenders (Blair et al., 2002) and consistent with preliminary reports of callosal anomalies in psychopathic individuals (Raine et al., 2003).

The possibility that psychopathic individuals suffer from impaired interhemispheric integration is also consistent with evidence that, under some conditions, these individuals are less responsive than nonpsychopathic individuals to distracting information presented in one channel or modality while they are processing other information (Jutai & Hare, 1983; Newman, Schmitt, & Voss, 1997). However, whether psychopathic persons’ supposed adeptness at screening out irrelevant information reflects reduced responsiveness to information in one hemisphere while processing information in the opposite hemisphere has not been investigated.

Prior Studies of Interhemispheric Integration

In recent years, Banich and colleagues (for a review, see Banich, 1998) have proposed that the ability to distribute information across both cerebral hemispheres of the brain is crucial for optimizing the performance of computationally complex tasks. In support of this view, Banich and colleagues have consistently demonstrated that as task complexity increases, across-field processing (i.e., a division of critical information across the LVF and RVF) becomes more advantageous to performance relative to within-field processing (Banich & Belger, 1990; Passarotti, Banich, Sood, & Wang, 2002; Weissman & Banich, 2000), a finding also replicated by other groups (e.g., Merola & Liederman, 1990; Yoshizaki, 2000).

Converging evidence supporting this model comes from numerous sources. First, neuroimaging studies have revealed that bilateral activity (which is consistent with a hemispheric division of labor) often increases as task demands become greater (e.g., Jonides et al., 1997; Klingberg, O’Sullivan, & Roland, 1997; Pollman, Zaidel, & von Cramon, 2003; Tsukiura et al., 2002). Second, children with phenylketonuria (which compromises the myelination of callosal neurons that connect cortical regions in opposite hemispheres) show reduced benefits of across-field processing for complex tasks (Banich, Passarotti, White, Nortz, & Steiner, 2000). Third, in populations exhibiting reduced overall processing capacity (e.g., normal children and older adults), the benefits of across-field processing occur at lower levels of task complexity (Banich, Passarotti, & Janes, 2000; Reuter-Lorenz, Stanczak, & Miller, 1999). These findings further support the view that effective interhemispheric integration is essential for optimizing the performance of computationally complex tasks.

Given the findings reviewed above, the study of interhemispheric integration may shed further light on the attention deficits evident in psychopathy. In particular, some of the deficits observed in psychopathic individuals in complex divided attention tasks (e.g., Kosson, 1996, 1998; Kosson & Newman, 1986) might be explained by impaired interhemispheric integration. More specifically, some of the performance deficits that have been attributed to LHA deficits might actually reflect difficulties in interhemispheric integration when left-hemisphere processing resources are taxed.

Overview of the Study

In the present study, we addressed three main questions. First, we examined whether psychopathic offenders exhibit performance deficits under conditions requiring interhemispheric integration. Second, we investigated whether psychopathic participants exhibit performance deficits under novel conditions designed to activate left hemisphere–specific systems. Third, we examined whether psychopathic participants’ performance deficits reflect an interaction between conditions that activate left-hemisphere systems and those that require interhemispheric integration.

To address these questions, we used a same–different version of the global–local paradigm (see Figure 1) that allowed us to manipulate both (a) the computational complexity of a selective attention task and (b) the degree to which the task required integration of information across the cerebral hemispheres (Weissman & Banich, 1999). In each trial, participants viewed an array of three hierarchical stimuli (e.g., a large, global “O” made up of small, local “A”s; Figure 1) and decided whether the target stimulus presented beneath fixation matched either of two comparison stimuli above fixation at a prespecified level (i.e., global or local), which varied across blocks. In half of the trials, no match was presented. In the other half, however, one of the comparison stimuli matched the target, and these were the trials that were crucial for testing our hypotheses. The computational complexity of the match decision was manipulated as follows: In the less complex (consistent) match trials, the target matched one of the comparison stimuli at both the relevant and the irrelevant levels (e.g., the matching stimuli were global Os made up of local As).

![Figure 1. Sample stimuli for global processing trials. On consistent match trials, the target and one of the comparison stimuli match both at the relevant (global) level and at the irrelevant (local) level. On inconsistent match trials, the target and comparison stimuli match at the relevant level but not at the irrelevant level. On across-field match trials, the target and its matching comparison stimulus are presented in different visual fields. LVF = left visual field; RVF = right visual field.](image-url)
the more complex (inconsistent) trials, the target matched one of the comparison stimuli only at the relevant level (e.g., at the global level, a global O made up of local Os matches a global O made up of local As). On such trials, the mismatch decision reached by attending to the irrelevant (e.g., local) level conflicted with the match decision reached by attending to the relevant (e.g., global) level (see Figure 1).

The degree to which information needed to be integrated across the cerebral hemispheres was manipulated by varying whether the matching stimuli were presented within the same visual field or divided across the LVF and RVF. In within-field trials, the matching comparison stimulus and target stimulus were presented within the same visual field. Thus, participants could determine that stimuli match without integrating information across the hemispheres. In across-field trials, however, the two matching stimuli were divided across the LVF and RVF such that interhemispheric integration was essential for a correct match decision to be reached. Using this paradigm, Weissman and Banich (1999) found that, relative to within-field processing, across-field processing aided performance significantly more for inconsistent trials than for consistent trials, in line with the view that interhemispheric integration is especially advantageous to performance when task complexity is relatively high.

In addition, this paradigm also included two manipulations of LHA, which were essential for testing our predictions about LHA deficits in psychopathy. First, during separate blocks, participants were required to compare target and comparison stimuli at the global level only versus the local level only. Evidence from studies with patient and nonclinical samples indicates that right-hemisphere systems favor holistic or global perceptual processing, whereas left-hemisphere systems are better suited for analytic or local processing (Lamb & Robertson, 1989; Martin, 1979; Van Kleeck, 1989). Similarly, neuroimaging studies show greater left-hemispheric activation during local processing and greater right-hemispheric activation during global processing (Fink et al., 1997; Weber, Schwarz, Kneifel, Treyer, & Buck, 2000). Second, the use of the right hand to respond during some blocks versus the left hand during other blocks provides a method of comparing performance under conditions with relatively greater priming of left-hemisphere motor systems (right hand conditions) versus relatively greater priming of right-hemisphere motor systems (left hand conditions; e.g., Baillet, Leahy, Singh, Shattuck, & Mosher, 2001; Lassen & Ingvar, 1990; Rizzolatti & Craighero, 1998).

Using the global–local task described above, we investigated whether psychopathic individuals' cognitive deficits under LHA conditions stem from deficits in interhemispheric integration, impaired processing under conditions of left-hemisphere activation, or an interaction of both types of deficits. If psychopathic individuals' performance deficits reflect an underlying difficulty with interhemispheric coordination, then such individuals should perform more poorly than those without psychopathy when left-hemisphere systems are more highly activated (i.e., when performing the local task and/or when responding with the right hand) but not when right-hemisphere systems are more highly activated (i.e., when performing the global task and/or responding with the left hand).

Finally, if psychopathic persons exhibit deficits in interhemispheric integration only under conditions of LHA, then interhemispheric deficits may be evident for such individuals under LHA but not RHA conditions. More specifically, psychopathic persons might benefit less from across-field processing than nonpsychopathic individuals only during local processing blocks and/or when using their right hand to respond. Furthermore, if interhemispheric integration deficits in psychopathic individuals occur mainly when left hemisphere resources are highly taxed, then any deficits observed during local processing blocks and/or when responding with the right hand might be more pronounced for the highly demanding inconsistent trials than in the less demanding consistent trials.

We also expected nonpsychopathic inmates to exhibit a Difficulty × Interhemispheric Communication interaction consistent with prior work by Banich and colleagues (see Banich, 1998): On trials presenting less demanding consistent stimulus arrays, such participants should perform as well under conditions that isolate a single hemisphere as under conditions that require interhemispheric integration. In contrast, on trials presenting inconsistent stimulus arrays, nonpsychopathic inmates should perform better under conditions that require interhemispheric integration than under conditions that allow isolated performance by a single hemisphere. Their performance provides a baseline against which to compare the performance of psychopathic participants.

Method

Participants

Participants were 58 (27 psychopathic and 31 nonpsychopathic) right-handed male inmates serving time for felonies or misdemeanors at a county jail near Chicago. All participants were European American, African American, Latino American/Hispanic, or of mixed ethnicity. Although most of the evidence for the construct validity of the Psychopathy Checklist (PCL) has been obtained with European Americans, evidence for its validity in African Americans and Latino Americans has also been reported (Cooke, Kosson, & Michie, 2001; Sullivan, Abramowitz, Lopez, & Kosson, in press). Participants’ ages ranged from 18 to 39 years at the time they were interviewed. Inmates on medications affecting cognition or emotion and who could not speak or read English were excluded. Intelligence was measured with the Shipley Institute of Living Scale—Revised (Zachary, 1986), and those with estimated IQs under 70 were excluded as well. There were no significant differences between psychopathic and nonpsychopathic offenders in age, education, or intelligence. Participants reporting impaired vision were asked to wear corrective lenses during testing. Demographics of the final sample are displayed in Table 1.

Procedure

All study procedures were approved by the Institutional Review Board of Rosalind Franklin University of Medicine and Science (formerly Finch University of Health Sciences / The Chicago Medical School). Each participant completed an interview with questions pertaining to items in the Hare Psychopathy Checklist—Revised (PCL–R; Hare, 1991). The PCL–R was completed based on inmate self-report, interviewers’ behavioral observations, and inmate pretrial services files available at the jail. After
the fixation point matched one of the two comparison stimuli above fixation at a prespecified level (i.e., global in some blocks, local in others) by pressing one of two keyboard keys (with the index or middle finger of the same hand) to indicate match versus mismatch. In 50% of the trials for each level (i.e., global and local), the bottom stimulus matched neither of the top two at the relevant level.

In the other 50% of trials for each level, however, the bottom stimulus did match one of the top two stimuli at the prespecified relevant level. In consistent match trials (50%), the bottom target stimulus matched one of the top two stimuli at both the relevant (e.g., global) level and the irrelevant (e.g., local) level; thus, the correct response could be determined by attending to either the relevant or irrelevant level of the hierarchical stimuli. In contrast, in inconsistent match trials (50%), the decision reached by attending to the irrelevant level (e.g., mismatch) conflicted with that reached by attending to the relevant level (e.g., match; see Figure 1). Thus, greater selective attention was required to respond correctly in inconsistent than in consistent trials.

In half of all match trials, the bottom target and its matching comparison stimulus appeared within the same visual field (within-field trials), whereas in the other half they appeared in opposite visual fields (across-field trials). In within-field (w) trials, the target and its matching comparison stimulus appeared equally often in the LVF (wLVF trials) and in the RVF (wRVF trials). Across-field (a) trials were classified according to the visual field in which the bottom target item appeared. Equally often, the target appeared in the RVF, with its match in the LVF (aRVF trials), or the target appeared in the LVF with its match in the RVF (aLVF trials). In all match trials, only one of the comparison stimuli matched the target stimulus; thus, one nonmatching stimulus was always present. Finally, we note that mismatch (i.e., nonmatching) trials were not analyzed, because it was not possible to assess effects of interhemispheric integration in these trials. Indeed, in mismatch trials, both within-field and across-field processing were required to decide that the bottom target stimulus matched neither of the top two comparison stimuli.

We used SuperLab 1.74 (Cedrus Corporation, 1997) to present the experimental stimuli and to record participants’ responses to them. Participants placed their heads in a chin rest facing the center of a computer screen, which was 25.9 in. (65.79 cm) directly in front of them. Participants completed 96 practice trials and 384 test trials. For the global-level blocks, there were 48 practice trials (24 match, 24 mismatch). Following these trials, participants performed 192 test trials at the global level (96 match, 96 mismatch). For half of the practice and test trials, participants responded with the right hand; for the other half, the participants used their left hand to respond. The local-level blocks were constructed similarly. The order of right- and left-hand blocks and the order in which global and local task blocks were presented were counterbalanced. Trial order within each block was randomized independently for each participant. (For further details on trial construction, see Weissman & Banich, 1999.)

**Results**

Alpha levels were set at .05, and all probability values were two-tailed. Participants with mean accuracy or response latency over three standard deviations from the group mean were considered outliers. As a result, two psychopathic and two nonpsychopathic participants were excluded from analyses, leaving 25 psychopathic and 29 nonpsychopathic participants in the total sample.

**Preliminary Analyses: Replication of Major Effects Reported by Weissman and Banich**

To examine whether the principal findings of Weissman and Banich (1999) replicated among our nonpsychopathic participants, we conducted a $2 \times 2 \times 2 \times 2$ (Level [global vs. local] $\times$ Complexity [Consistent vs. Inconsistent] $\times$ Interhemispheric
Communication [required/across-field vs. not required/within-field] × Visual Field of Target (LVF vs. RVF), repeated measures analysis of variance (ANOVA) for this group.

Response Latency

As expected, we observed a Complexity × Interhemispheric Communication interaction, F(1, 28) = 13.60, p = .001. On simple, consistent trials, nonpsychopathic participants did not benefit from interhemispheric communication (across-field = 605 ms; within-field = 597 ms), t(28) < 1.1. However, on inconsistent trials, nonpsychopathic participants were significantly faster on across-field (692 ms) than on within-field trials (739 ms), t(28) = 3.55, p = .001, Cohen’s d (effect size) = .67. Further corroborating Weissman and Banich (1999), a t test revealed that the difference in reaction time between inconsistent and consistent trials (i.e., interference due to complexity) was significantly smaller on across-field trials than on within-field trials (87 vs. 143 ms), t(28) = 3.60, p = .001 (see also Figure 2).

In addition, corroborating the assumption that local processing differentially activated left-hemisphere systems, the Level × Visual Field interaction was significant, F(1, 28) = 16.07, p < .001. During local processing blocks, response latencies were faster for RVF than for LVF targets, t(28) = 3.36, p = .002; however, during global blocks, responses were nonsignificantly faster for LVF than for RVF targets, t(28) = 1.23, p > .20.1

To address whether use of the right hand differentially activated left-hemisphere systems, we also conducted a $2 \times 2 \times 2 \times 2$ (Hand × Complexity × Interhemispheric Communication × Visual Field) ANOVA. This analysis yielded no significant Hand × Visual Field interactions.

Accuracy

As expected, a Complexity × Interhemispheric Communication interaction was also found for accuracy, F(1, 28) = 5.52, p = .026. In this case, for consistent trials, nonpsychopathic individuals were more accurate on within-field trials (95.3%) than on across-field trials (92.9%), t(28) = 2.49, p = .019, d = .47. Although they were not significantly more accurate on inconsistent trials requiring interhemispheric integration (across-field vs. within-field accuracy = 87.6% vs. 85.4%), t(28) = 1.11, ns, a t test revealed less interference (as a function of inconsistency) on across-field than on within-field trials (5.2% vs. 9.8%), t(28) = 2.35, p = .026. The Level × Visual Field interaction was not significant, F(1, 28) = 2.25, p = .14, but the Level × Visual Field × Complexity interaction was significant, F(1, 28) = 6.24, p = .019. Consistent with design assumptions, nonpsychopathic participants were more accurate on RVF than on LVF trials during local processing blocks (82.9% vs. 78.0%), but the difference was significant only for inconsistent trials, F(1, 28) = 6.64, p = .016.2

A $2 \times 2 \times 2 \times 2$ (Hand × Complexity × Visual Field × Interhemispheric Communication) ANOVA yielded no Hand × Visual Field interactions, but the Hand × Visual Field × Interhemispheric Communication term approached significance, F(1, 28) = 3.25, p = .082 (see Footnote 1).

Additional Findings

Although less central for testing principal hypotheses, it is noteworthy that, consistent with Weissman and Banich (1999), ANOVAs revealed faster and more accurate responses for non-

---

1 Following Weissman and Banich (1999), we also repeated these ANOVAs limited to within-field trials. The Level × Visual Field interaction was again significant, F(1, 28) = 7.33, p = .01. As expected, responses to local trials within the RVF were faster than responses to local trials within the LVF, t(28) = 2.38, p = .024. In contrast, response latencies on global trials were not significantly faster for within-LVF than for within-RVF trials, t(28) < 1. Results were less robust for the hand of response manipulation but approached significance for accuracy, with nonsignificantly more accurate performance for wRVF than wLVF trials completed with the right hand. Although not central to this study, some evidence suggests that the hemisphere making the match decision on across-field trials may not be the same as the hemisphere initially receiving the target information (Banich, Stolar, Heller, & Goldman, 1992). For this reason, within-field trials are especially important for establishing the effectiveness of the local processing manipulation.

2 There was also a Level × Hemisphere × Complexity × Interhemispheric Communication interaction, F(1, 28) = 13.77, p = .001, indicating that, during local blocks, RVF performance exceeded LVF performance only on within-field local inconsistent trials. On within-field global inconsistent trials, LVF performance was more accurate than RVF performance, but on across-field global inconsistent trials, RVF performance exceeded LVF performance.
psychopathic participants on global than on local trials, $F(1, 28) = 46.32, p < .001$, for response latency, and $F(1, 28) = 11.89, p = .002$, for accuracy. Responses were also faster and more accurate for consistent trials than for inconsistent trials, $F(1, 28) = 161.41, 94.77, ps < .001$, respectively. Further corroborating Weissman and Banich (1999), Level $\times$ Complexity interactions, $F(1, 28) = 9.93, p < .004$, and $F(1, 28) = 25.37, p < .001$, revealed that inconsistent information caused more interference on local trials than on global trials, respectively (149 vs. 81 ms; 11.8% vs. 3.3%). These results for nonpsychopathic inmates correspond well with the findings of Weissman and Banich (1999) and are consistent with the hypothesis that nonpsychopathic individuals perform similarly to normal populations. Given these findings, the nonpsychopathic group appears to represent an adequate control group for comparisons with the psychopathic group.

**Tests of Group Differences in Interhemispheric Integration**

**Between-group analyses addressing interhemispheric communication in psychopathic participants.** To address whether psychopathic participants exhibit reduced benefits of interhemispheric integration relative to those without psychopathy, $2 \times 2$ (Group $\times$ Interhemispheric Communication) ANOVAs were conducted separately for inconsistent trials and for consistent trials. The Group $\times$ Interhemispheric Communication interaction was not significant in either analysis, both $F_5(1, 28) < 1$. Parallel analyses conducted for accuracy also yielded no evidence of Group $\times$ Interhemispheric Communication, both $F_5(1, 52) < 1$. In summary, these analyses revealed no overall group differences in interhemispheric communication.

We also conducted planned comparisons to examine directly whether psychopathic inmates responded more slowly or less accurately than nonpsychopathic inmates for across-field conditions (requiring interhemispheric communication) and for within-field trials. Given the consistent evidence for Complexity $\times$ Interhemispheric Communication interactions, comparisons were conducted separately for consistent and for inconsistent trials. Contrary to hypotheses, psychopathic participants were no slower than nonpsychopathic participants on inconsistent across-field trials, $t(52) = 1.38$, although they tended to be less accurate on such trials than those without psychopathy (83.1% vs. 87.6%), $t(52) = 1.79, p = .080, d = .50$. However, psychopathic participants also tended to be slower than nonpsychopathic participants (685 vs. 597 ms) on consistent within-field trials, $t(52) = 1.78, p = .081, d = .49$, and less accurate than nonpsychopathic participants (80.5% vs. 85.4%) on inconsistent within-field trials, $t(52) = 1.68, p = .099, d = .47$ (see Figures 2 and 3). Thus, there were several trends toward significant group differences not specific to conditions requiring interhemispheric integration.

**Within-group analyses addressing interhemispheric communication in psychopathic participants.** We also examined the possibility that, if psychopathic inmates are characterized by a severe impairment in interhemispheric integration, then they might not display the across-field advantages typically seen for complex conditions. To address this possibility, we conducted $2 \times 2 \times 2 \times 2$ (Level $\times$ Complexity $\times$ Interhemispheric Communication $\times$ Visual Field) repeated measures ANOVAs parallel to those reported for nonpsychopathic participants above. In these analyses, the Complexity $\times$ Interhemispheric Communication interactions were only marginally significant, $F(1, 24) = 3.97, p = .058$, for response latency; $F(1, 24) = 3.74, p = .065$, for accuracy.\(^3\) We then compared the response latency and accuracy of psychopathic inmates on inconsistent across-field trials to that on inconsistent within-field trials. Psychopathic participants, like their nonpsychopathic counterparts, responded significantly faster on inconsistent, within-field trials. Psychopathic responses were slightly but significantly faster on across-field than on within-field trials. Although there were slight differences from findings of Weissman and Banich in the pattern of higher order interactions, even such interactions were generally similar to those reported by Weissman and Banich. Additional information about higher order interactions is provided in Lopez (2001) and available on request to Mabel Lopez.

\(^3\) Also consistent with Weissman and Banich, a main effect for interhemispheric communication, $F(1, 28) = 6.87, p = .014$, indicated that responses were slightly but significantly faster on across-field than on within-field trials. Although there were slight differences from findings of Weissman and Banich in the pattern of higher order interactions, even such interactions were generally similar to those reported by Weissman and Banich. Additional information about higher order interactions is provided in Lopez (2001) and available on request to Mabel Lopez.

\(^4\) To ensure that we were not ignoring a significant Group $\times$ Complexity $\times$ Interhemispheric Communication interaction, we also conducted $2 \times 2 \times 2 \times 2$ (Group $\times$ Level $\times$ Complexity $\times$ Hemisphere $\times$ Interhemispheric Communication) repeated measures ANOVAs for both response latency and accuracy. Both ANOVAs indicated that there were no significant Group $\times$ Complexity $\times$ Interhemispheric Communication interactions, both $F(1, 52) < 1$.
across-field trials than on inconsistent, within-field trials (765 vs. 822 ms), \( t(24) = 3.27, p = .003, d = .67 \). Like nonpsychopathic participants, those with psychopathy exhibited no significant difference between response latencies for consistent across-field versus consistent within-field trials (683 vs. 685 ms), \( t(24) < 1 \). Also like nonpsychopathic participants, the psychopathic group was only nonsignificantly more accurate on inconsistent across-field trials than on inconsistent within-field trials (83.1\% vs. 80.5\%), \( t(24) = 1.65, p = .113, d = .34 \). Moreover, as in nonpsychopathic participants, \( t \) tests revealed smaller difference scores (i.e., less interference) due to complexity on across-field trials than on within-field trials. This effect approached significance for both response latency (costs = 82 vs. 137 ms), \( t(24) = 2.01, p = .055 \), and for accuracy (costs = 7.8\% vs. 11.8\%), \( t(24) = 1.93, p = .065 \).

**Tests of Group Differences in Performance Under Left-Hemisphere Activation Conditions**

To address whether psychopathic participants performed more poorly than nonpsychopathic participants under LHA conditions (i.e., during local blocks), we conducted a 2 × 2 Group × Level (global vs. local) ANOVA. The Group × Level interaction was significant, \( F(1, 52) = 5.43, p = .024 \). Comparisons based on marginal means revealed that psychopathic participants were slower than nonpsychopathic participants during local processing blocks, \( F(1, 52) = 4.39, p = .04, d = .58 \), but not during global blocks, \( F(1, 52) < 1, d = .19 \). A parallel analysis for accuracy yielded no Group × Level interaction, \( F(1, 52) < 1 \). Nevertheless, the effect size for psychopathic participants’ poorer accuracy during local blocks was moderate, \( t(52) = 1.63, p = .11 \), Cohen’s \( d = .45 \), whereas the effect size for the group difference in accuracy during global blocks was small, \( t(52) < 1, d = .24 \).

Although the lack of significant of Hand × Visual Field interactions (see Preliminary Analyses) casts doubt on the power of the hand of response manipulation, we also examined whether psychopathic participants performed more poorly than nonpsychopathic participants during right-handed versus left-handed blocks. For both response latency and accuracy, 2 × 2 Group × Hand ANOVAs yielded no evidence of Group × Hand interactions, \( F(1, 52) < 1 \). However, the accuracy analysis yielded a marginally significant deficit for psychopathic participants responding with the right hand, \( F(1, 52) = 4.02, p = .05, d = .56 \); with the left hand, \( F(1, 52) = 1.83, p = .18, d = .38 \). In summary, the Group × Level interaction for response latency and the pattern of group differences under local processing condition were consistent with the LHA hypothesis. Results for hand of response were less consistent with the hypothesis, an issue addressed further below.

**Tests of the Interhemispheric Interaction × Left Hemisphere Activation Interaction Hypothesis**

Tests involving local versus global processing. The Interhemispheric Communication × LHA Hypothesis states that psychopathic participants exhibit a reduced advantage for interhemispheric integration relative to the nonpsychopathic participants under LHA but not RHA conditions. To address this hypothesis for level (local vs. global blocks), we conducted two 2 × 2 × 2 (Group × Interhemispheric Communication × Level × Complexity) ANOVAs, one for response latency and one for accuracy. No higher order interactions involving group were significant in either analysis. However, the Group × Level interaction reported earlier was again significant in the response latency analysis, \( F(1, 52) = 5.45, p = .023 \).

We also examined directly whether psychopathic participants performed more slowly and/or less accurately than nonpsychopathic inmates on local across-field trials but not on local within-field trials or on global trials. Means and standard errors for these comparisons are shown in Table 2. Psychopathic participants were marginally slower than their nonpsychopathic counterparts (907 vs. 779 ms) on local, inconsistent across-field trials, \( t(38.81) = 2.04, p = .048, d = .65 \), and on local, consistent within-field trials (794 vs. 648 ms), \( t(36.06) = 2.21, p = .034, d = .74 \), and nonsignificantly slower (944 vs. 830 ms) on local, inconsistent within-field trials, \( t(52) = 1.65, p = .105, d = .46 \). In

| Table 2 | Means and Standard Errors (SE) for Response Latency and Accuracy for Nonpsychopathic and Psychopathic Participants During Local and Global Processing Blocks Under Conditions of Varying Interhemispheric Integration Requirements and Complexity |
|---------|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
|         | Response latency                                                                                | Accuracy                                                                                       |
|         | Nonpsychopathic                                  | Psychopathic                                  | Nonpsychopathic                                  | Psychopathic                                  |
| Condition | M (SE)                                      | M (SE)                                      | M (SE)                                           | M (SE)                                      |
| Local   |                                             |                                             |                                                  |                                            |
| Inconsistent across | 779 (40)  | 907 (54)  | 81.9 (2.3)  | 74.3 (2.8)  |
| Inconsistent within | 830 (42)  | 944 (57)  | 79.0 (3.0)  | 72.7 (3.5)  |
| Consistent across | 665 (32)  | 796 (56)* | 91.4 (2.0)  | 88.8 (2.6)  |
| Consistent within | 648 (30)* | 794 (59)* | 93.1 (2.0)  | 89.3 (2.3)  |
| Global   |                                             |                                             |                                                  |                                            |
| Inconsistent across | 606 (32)  | 626 (43)  | 93.4 (2.0)  | 91.8 (2.5)  |
| Inconsistent within | 649 (31)  | 699 (45)  | 91.8 (1.4)  | 88.3 (2.7)  |
| Consistent across | 545 (29)  | 570 (27)  | 94.4 (1.5)  | 92.8 (2.6)  |
| Consistent within | 546 (29)  | 576 (34)  | 97.4 (0.6)  | 95.3 (2.4)  |

* Group means for psychopathic and nonpsychopathic participants are significantly different, \( p < .05 \).
contrast, psychopathic participants were not slower than those without psychopathy on any types of trials during global blocks, all $t$s(52) < 1. Thus, participants with psychopathy were slower than nonpsychopathic individuals under conditions of LHA, regardless of task complexity or demand for interhemispheric integration.

Psychopathic participants were also less accurate than nonpsychopathic participants on local, inconsistent across-field trials (74% vs. 82%), $t(52) = 2.10$, $p = .041$, $d = .58$ (see Figure 5). However, the groups did not differ in accuracy on local inconsistent within-field trials (73% vs. 79%), $t(52) = 1.40$, ns, or on local consistent trials, both $t$s(52) ≤ 1.3, ns. Nevertheless, although psychopathic participants’ accuracy deficits were only reliable under LHA conditions demanding interhemispheric communication, the overall pattern of group differences in accuracy and response latency suggests a more general deficit under local processing conditions. In contrast, under global processing conditions, the groups did not differ in response latency or accuracy, regardless of demands for interhemispheric integration, all $t$s(52) ≤ 1.2, ns (see Figures 6 and 7).

Tests involving right-handed versus left-handed responses. To address whether psychopathic participants performed more poorly than nonpsychopathic participants during right-handed versus left-handed blocks, we conducted parallel ANOVAs with two levels of hand (right vs. left) instead of relevant level (global vs. local). In this case, the response latency analysis yielded no interactions involving group. However, the accuracy analysis yielded a Group × Hand × Complexity interaction, $F(1, 52) = 5.15$, $p = .027$, which reflected psychopathic participants’ poorer accuracy on inconsistent trials only when completed with the right hand, $F(1, 52) = 7.14$, $p = .01$, $d = .74$; for inconsistent trials with the left hand, $F(1, 52) = 1.24$, $p < .20$, $d = .31$.

Although direct comparisons of psychopathic and nonpsychopathic participants revealed no significant differences in response latency for across-field trials completed with the right hand, $t(52) = 1.1$, ns, or for comparison (i.e., within-field) trials, psychopathic participants were less accurate than those without psychopathy (83.3% vs. 89.2%) on inconsistent across-field trials with the right hand, $t(52) = 2.38$, $p = .021$, $d = .66$. However, their
deficit was not specific to trials demanding interhemispheric integration: They were also less accurate than nonpsychopathic participants on inconsistent within-field trials with the right hand (78.8% vs. 85.6%), t(52) = 2.15, p = .036, d = .60.\(^5\) In contrast, the groups did not differ in accuracy with the left hand (all ts < 1.6, ns). Means and standard errors for these comparisons are shown in Table 3. Taken together, these analyses replicate LHA deficits reported previously (Kosson, 1996, 1998) and suggest that psychopathic participants’ LHA deficits are not specific to conditions requiring interhemispheric communication.

In summary, analyses of the interaction hypothesis provided no evidence for poorer interhemispheric integration in psychopathic participants under LHA or RHA. However, these analyses provided additional evidence of generally slower responses for psychopathic participants during local blocks and poorer accuracy for these individuals on inconsistent trials when using the right hand.

Discussion

The results of the present study suggest that psychopathic individuals benefit from interhemispheric integration just as much as those without psychopathy, because on complex tasks they perform faster when information is divided between the hemispheres. Moreover, psychopathic participants performed no worse than nonpsychopathic participants when processing information across the two visual fields. Although these findings do not support the hypothesis that interhemispheric integration is disrupted in psychopathic individuals, they are consistent with the literature that reports generally intact cognitive functioning in such individuals (e.g., Smith et al., 1992).

Notably, this study corroborated previous reports of LHA deficits in psychopathy, demonstrating that LHA deficits generalize to global–local conditions. Psychopathic participants were slower than nonpsychopathic participants under local processing conditions that primed left-hemisphere perceptual systems. Because psychopathic participants performed more slowly under both LHA conditions that required interhemispheric integration and those conditions that did not, the findings suggest that the local processing deficits were relatively general (see Figures 4 and 5). Although overall accuracy deficits for psychopathic individuals were not seen during local processing blocks, the effect size for the nonsignificant group difference in accuracy under local conditions was nearly twice as large as that for the group difference in accuracy under global conditions (ds = .45 vs. .24).

The present study also demonstrated accuracy deficits for psychopathic participants when using the right hand. These individuals exhibited a marginally significant deficit in accuracy analyses when using their right hand. More important, the Group × Hand × Complexity interaction indicated that psychopathic participants performed less accurately than those without psychopathy only on inconsistent trials when using the right hand. Although less general than psychopathic individuals’ deficit during local processing blocks, this finding corroborates earlier studies demonstrating deficits for psychopathic offenders when using their right hand more often than their left hand (Kosson, 1996, 1998). Similar findings have recently been reported in other psychopathic samples (Llanes & Kosson, 2006; Lorenz & Newman, 2002). However, our finding that the deficit was specific to complex, inconsistent trials suggests that the deficit may be evident only under attentionally demanding conditions (cf. Suchy & Kosson, 2005).

A question that arises from this study is whether the deficits seen in psychopathic individuals are specific to left-hemisphere activation or to a more general difficulty in the processing of local information. Both current findings and other studies suggest that the deficits do not reflect a general difficulty in processing local information. First, the current study revealed deficits for psychopathic participants on inconsistent trials when using the right hand, collapsing across level of processing; thus, the deficits of such individuals were not entirely limited to conditions of local processing. Second, Kosson, Miller, Byrnes, and Leveroni (in press) addressed this issue by administering a global–local paradigm under three conditions: (a) where 80% of the targets occurred at the local level (to induce LHA); (b) where 80% of targets occurred at the global level (to induce RHA); and (c) where 50% of targets occurred at each level (a neutral condition). In that study, the order of the LHA and RHA conditions was counterbalanced, and among

\(^5\) In addition, psychopathic participants were nonsignificantly slower than nonpsychopathic participants when using the right hand for simple, across-field trials, t(52) = 1.66, p = .104, and when using the left hand for simple, within-field trials, t(52) = 1.79, p = .079.
participants first exposed to the LHA condition, PCL–R scores correlated negatively with response speed for identifying both local and global targets in the LHA condition. In contrast, among participants first exposed to the RHA condition, psychopathy scores were unrelated to performance for local or global targets under any condition. This pattern of findings suggests that psychopathic individuals are not always poorer at processing local information, (e.g., when the right hemisphere is primed) and that their performance deficits include global processing when conditions are designed to prime left hemisphere perceptual and motor systems. Finally, given that past studies found LHA deficits in visual, auditory, and intermodal paradigms that did not include global or local stimulus processing (Kosson, 1996, 1998; Suchy & Kosson, 2005), it appears likely that the LHA deficits seen in this study are specific to conditions that activate left-hemisphere systems and not to conditions requiring local processing.

This study also served to establish criminal nonpsychopathic participants as an adequate control group in studies of interhemispheric integration. In general, such individuals behaved similarly to the college students tested in Weissman and Banich (1999). Specifically, on more attentionally demanding inconsistent trials, nonpsychopathic participants benefited from having target and matching comparison stimuli presented to different visual fields. Moreover, the findings for nonpsychopathic participants replicated commonly observed effects such as better performance for global than for local targets and on consistent than inconsistent trials.

This is the first known study to assess the interhemispheric integration capacity of psychopathic individuals. Although this study demonstrates that such individuals can benefit from interhemispheric communication in a similar fashion to those without psychopathy, it does not answer all questions relevant to interhemispheric integration in psychopathic individuals. Additional studies are needed to further explore the relationship between interhemispheric processing and psychopathy. For instance, it may be argued that the same–different global–local paradigm contained too many manipulations that primed left-hemisphere systems (i.e.,

Table 3

<table>
<thead>
<tr>
<th>Condition</th>
<th>Nonpsychopathic</th>
<th>Psychopathic</th>
<th>Nonpsychopathic</th>
<th>Psychopathic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SE)</td>
<td>M (SE)</td>
<td>M (SE)</td>
<td>M (SE)</td>
</tr>
<tr>
<td>Right hand</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inconsistent across</td>
<td>689 (35)</td>
<td>756 (48)</td>
<td>89.2 (1.7)*</td>
<td>83.3 (1.8)*</td>
</tr>
<tr>
<td>Inconsistent within</td>
<td>727 (35)</td>
<td>814 (49)</td>
<td>85.6 (2.0)*</td>
<td>78.8 (2.5)*</td>
</tr>
<tr>
<td>Consistent across</td>
<td>594 (30)</td>
<td>678 (42)</td>
<td>91.4 (1.5)</td>
<td>90.8 (1.8)</td>
</tr>
<tr>
<td>Consistent within</td>
<td>591 (29)</td>
<td>676 (47)</td>
<td>95.4 (1.0)</td>
<td>92.2 (1.7)</td>
</tr>
<tr>
<td>Left hand</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inconsistent across</td>
<td>697 (38)</td>
<td>774 (40)</td>
<td>86.1 (1.8)</td>
<td>82.8 (2.8)</td>
</tr>
<tr>
<td>Inconsistent within</td>
<td>751 (36)</td>
<td>830 (46)</td>
<td>85.2 (1.9)</td>
<td>82.2 (2.7)</td>
</tr>
<tr>
<td>Consistent across</td>
<td>616 (33)</td>
<td>688 (40)</td>
<td>94.4 (1.3)</td>
<td>90.8 (2.0)</td>
</tr>
<tr>
<td>Consistent within</td>
<td>603 (28)</td>
<td>694 (44)</td>
<td>95.1 (1.1)</td>
<td>92.5 (1.6)</td>
</tr>
</tbody>
</table>

* Group means for psychopathic and nonpsychopathic participants are significantly different, $p < .05$. 

![Figure 7. Mean accuracy (percentage correct) for psychopathic and nonpsychopathic participants on global block trials as a function of difficulty (consistent vs. inconsistent stimuli) and requirements for interhemispheric communication.](image-url)
local processing, within RVF–LH trials, and right hand use). The availability of these various manipulations allowed us to examine the LHA hypothesis under multiple conditions. However, the use of multiple analyses to test the different levels of processing and different response hands may have resulted in inflation of alpha levels. Moreover, the absence of a significant Hand of Response × Hemisphere interaction for nonpsychopathic individuals suggests that the hand of response manipulation was not a very effective means of activating left-hemisphere systems. Rather, it appears that cognitive manipulations (such as local processing blocks) or cognitive manipulations tied to response manipulations (as in prior LHA studies) are more effective. In addition, this paradigm did not allow for absolute isolation of left-hemisphere resources because, even on within-field trials, stimuli were presented in both visual fields. Nevertheless, bilateral presentation of the stimulus was appropriate for this study, because it was designed to study the interhemispheric integration capacity of individuals with psychopathy. Furthermore, although LHA deficits were not specific to conditions eliciting integration in this study, it remains possible that subtle interhemispheric communication deficits will be seen in psychopathic individuals under other conditions.

In summary, current findings provide evidence for adequate interhemispheric integration capacity in psychopathic offenders while demonstrating the generality of LHA deficits to global–local processing. Nevertheless, given that interhemispheric integration deficits have been associated with emotional, attentional, and language systems in humans (Gazzaniga, 2000), and that all of these systems have been reported to be abnormal in psychopathic individuals (e.g., Howland, Kosson, Patterson, & Newman, 1993; Louth, Williamson, Alpert, Pouget, & Hare, 1998; William- son, Harpur, & Hare, 1991) additional study of interhemispheric integration in psychopathic individuals appears warranted.

References


Received October 18, 2004

Revision received April 20, 2006

Accepted April 24, 2006