Vigilance and Iconic Memory in Children at High Risk for Alcoholism*

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ABSTRACT. Objective: Previous studies report reduced visual event-related potential (ERP) amplitudes in young males at high risk for alcoholism. These findings could involve difficulties at several stages of visual processing. This study was aimed at examining vigilance performance and iconic memory functions in children at high risk or low risk for alcoholism. Method: Sustained vigilance and retrieval from iconic memory were evaluated in 34 (29 male) white children at high risk and 47 (25 male) white children at low risk for developing alcoholism. Children were also grouped according to gender and age (younger: 8-12 years; older: 13-18 years). Results: No differences in visual sensitivity, response criterion or reaction time were associated with risk status on the degraded visual stimulus version of the Continuous Performance Test. For the Span of Apprehension, no differences were found due to risk status when only 1 or 5 distractors were presented, although with 9 distractors a significant effect of risk status was found when it was tested as an interaction with gender and age (decreased accuracy for older high-risk boys compared to older low-risk boys). Conclusions: These findings suggest that ERP deviations are not attributable to stages of visual processing deficits, but represent difficulty involving more complex utilization of information. Implications of these results are that the differences between high- and low-risk children that have been reported previously for visual ERP components (e.g., P300) are not attributable to deficits of attentional or iconic memory mechanisms. (J. Stud. Alcohol 58: 428-434, 1997)

There has been an accumulation of evidence suggesting that aspects of information processing at successive stages of complexity differ among children at high risk for alcoholism as compared to children at low risk. At stages of processing involving sensory-motor integration, performance on tests of static ataxia show deficits in high-risk children (Hill et al., 1987; Hill and Steinhauer, 1993b). Behavioral evaluation indicates that children of alcoholic parents exhibit learning impairments on a paired-associates task using visuospatial stimuli (Schandler et al., 1988).

Several studies have reported that children from high-risk families show a reduction in the amplitude of the P300 component of the event-related brain potential (ERP). P300 is a scalp positivity occurring approximately one-third of a second after stimulus presentation. P300 reduction has been reported most consistently for young (8-13 years) boys on tasks in which complex processing of visual stimuli was required (Begleiter et al., 1984; Hill et al., 1995; Hill and Steinhauer, 1993a; Whipple et al., 1988). Moreover, reduction in auditory P300 among high-risk children appears to predict involvement with substance abuse 8 years later (Hill et al., 1995). These findings offer critical evidence for deviations in cognitive processing between risk groups. However, the particular types of deficits that may contribute to P300 reduction have not previously been investigated. Thus, it is not clear whether the reported changes in ERP amplitudes reflect deviations in perceptual stages of processing activity associated with familial risk status. The present study examined performance of children from families at high or low risk for alcoholism on visual tests of vigilance (Continuous Performance Test; CPT) and of retrieval of information from iconic memory (Span of Apprehension; SOA).

A variety of behavioral procedures have been employed to study perceptual processes. Among these are tasks that evaluate the maintenance of vigilance, which is critical in the recording of event-related potentials. Vigilance, or sustained attention, has been evaluated by varieties of continuous performance tests. The subject must detect whether or not a specific target or target sequence is present on each trial (Rosvold et al., 1956). Using analyses derived from signal detection theory, separate estimates of response sensitivity (the ability to discriminate a signal from background distractors or noise) and response criterion (a subject’s willingness to respond) can be obtained. Response criterion may change independently of the subject’s sensitivity level. Sensitivity may be measured parametrically through the calculation of d’ level, which represents the difference in standard scores between the proportion of signals correctly detected (hits) and the proportion of responses to nontargets (false alarms). Similarly, parametric measures of response criterion (β) can be calculated, with higher measures of β indicative of a more cautious tendency to respond. Nuechterlein (1991) has discussed these measures as applied to vigilance tasks in psychopathological research.

Although designed originally to assess performance deficits due to brain damage (Rosvold et al., 1956), the CPT...
is sensitive to impaired vigilance in other populations, including hyperactive children (Barkley et al., 1990; O’Dougherty et al., 1984; Sykes et al., 1973) and children of other high-risk populations, most notably the offspring of schizophrenic parents (Erlenmeyer-Kimling and Cornblatt, 1978; Grunebaum et al., 1974; Nuechterlein, 1983). Sensitivity estimates using a degraded stimulus CPT appear reliable over time in adults (Nuechterlein, 1985), although developmental changes have not been described in detail. While rapid decreases in visual sensitivity do occur within a session (Nuechterlein et al., 1983), sensitivity is reliable within individuals over repeated sessions.

In order to perform the ERP tasks correctly, it is necessary that information provided by the visual stimulus be available to the subject beyond the period of stimulus exposure. For example, in the visual task employed by Begleiter et al. (1984) and Hill and Steinhauser (1993a), the subject is required to recognize the orientation of a head (nose up or down) and ear (left or right) after a brief (33 msec) presentation. One possible explanation for the observed decreased P300 amplitudes among the high-risk children in these studies is that the high-risk children are impaired in their ability to extract relevant information from short-term iconic memory, a form of brief visual storage.

The Span of Apprehension refers to the number of separate stimuli that can be noted in a single sensory percept. A typical experimental paradigm involves presentation of multiple visual stimuli in an array, such as letters, with a brief exposure duration that does not permit multiple fixations. Retrieval of information from iconic memory using a partial report Span of Apprehension procedure (Estes and Taylor, 1966; Sperling, 1960) provides greater access to information than tasks in which subjects are asked to report all stimuli in a visual array. Partial report refers to the fact that subjects are asked to search a stimulus array either for a limited number of possible targets or for items in the array emphasized by a cue. Versions of the partial report Span of Apprehension have shown poorer scanning and retrieval processes in schizophrenic children (Caplan et al., 1990) and in children at risk for schizophrenia (Asarnow et al., 1977, 1978, 1991). P300 amplitude reduction in combination with behavioral impairment has been observed in schizophrenic children during performance of both the Span of Apprehension and the Continuous Performance Test (Strandburg et al., 1984, 1990).

Behavioral findings are presented for the Continuous Performance Test and the Span of Apprehension. These tests are used as measures of vigilance and of retrieval from iconic memory, respectively, for children at high risk for alcoholism. These same children were evaluated using a visual ERP task which has been found to elicit decreased P300 amplitudes in high-risk children compared to control children (Hill and Steinhauser, 1993a; Hill et al., 1995). In these studies, the major difference in event-related potential activity was seen between younger (8-12 years old) high- and low-risk boys. Given that finding, it was of special interest to compare behavioral performance on these visual tasks in relation to risk status, gender and age.

Method

A total of 101 white children participated in the study. The children were drawn from two groups: high-risk and low-risk. The high-risk group of 54 (29 male) children from 37 different families had an exceptionally high familial loading of alcoholism. The low-risk group of 47 (25 male) children from 29 different families had no first- or second-degree relatives with diagnosed alcoholism.

The high-risk families were part of a larger family study of alcoholism (Cognitive and Personality Factors Family Study; CPFFS) that includes multiple extended pedigrees with multigenerational alcoholism, largely uncontaminated by other psychopathology (all first-degree relatives were required to be free of DSM-III [Axis I] disorders). These high-risk families had been ascertained through a proband set comprised of a pair of alcoholic brothers with an early onset of alcohol dependence (mean [±SD] = 18.8 ± 1.1 years). This ascertainment strategy results in a more severe form of familial alcoholism (Hill, 1992; Hill and Neiswanger, 1997). While the fathers, uncles and grand-children were frequently alcoholic, the mothers of these children were rarely alcohol dependent. Of these 54 children, 33 had an alcoholic father, 18 had neither parent alcoholic, 1 had an alcoholic mother and 2 had both parents who were alcoholic. Two of the three mothers who met a lifetime diagnosis of alcoholism denied drinking during pregnancy, while the third mother ceased drinking after the first 3 months when her pregnancy was confirmed. The presence of alcoholism or other psychopathology was determined for these brothers and their first-degree relatives through face-to-face interviews (Diagnostic Interview Schedule; DIS), allowing for DSM-III and Feighner Criteria to be applied. The resulting high-density families represent a form of alcoholism that appears to be mediated by a major effect, although probably not a single major locus (Aston and Hill, 1990; Yuan et al., 1996). These children have an average of four first- and second-degree relatives who are alcoholic. Thus, these families represent a greater familial loading for alcoholism than is obtained in studies where the only criterion is a report that the father is alcoholic.

The low-risk families were also part of the larger study and included multiple members of pedigrees selected for absence of psychopathology. These families were selected from among community volunteers. Families qualified for participation by having both multiple siblings and at least one parent available for personal interview, as well as absence of DSM-III Axis I psychopathology, including alcoholism, upon direct DIS interview. In order to be sure that the structural characteristics of the two family types were similar, the families were selected through a pair of male siblings. All available siblings and parents were interviewed to confirm
the absence of psychopathology in the designated sibling pair and the first-degree relatives.

As a result, all available children between the ages of 8-18 who were from the two family types were included in the study. Multiple children from the same nuclear family, where available, were included.

The children were well matched on age. In addition, an attempt was made to match the children for socioeconomic status of their parents. The mean (± SD) age was 11.14 ± 3.3 years for high-risk boys and 11.24 ± 3.5 years for high-risk girls. Mean age for control boys was calculated to be 11.08 ± 2.9 years and mean age for the girls averaged 11.32 ± 3.5 years. The socioeconomic status (SES) of the two groups was determined by employing Hollingshead’s Four Factor Index of Social Status (Hollingshead, unpublished manuscript). Comparing the high- and low-risk groups revealed largely similar socioeconomic levels. A chi-square analysis did not reveal differences among the two risk groups when children from Levels I and II were compared with those from Levels III, IV and V (highest SES) in a 2 × 2 analysis (X^2 = 3.38, 1 df, p < .06). Because the average age of the children was 11 years, there was negligible contact with alcohol and drugs. Clinical syndromes were assessed by a trained interviewer who administered the K-SADS (Schedule for Affective Disorders and Schizophrenia for School-Aged Children) (Chambers et al., 1985) which was always followed by an assessment by a second clinician (advanced psychiatric resident or clinical psychologist), both of whom were blind to the child’s familial status. From these evaluations, a consensus diagnosis was established. Alcohol abuse was diagnosed in two of the high-risk offspring, but in none of the low-risk offspring. Three of the high-risk children and one of the low-risk children met criteria for Conduct Disorder. There were no significant differences between risk groups in the rates of these disorders. Urine screens indicated that all children were free of drugs at the time of testing.

**Procedures**

Testing was carried out during the early afternoon. During the morning of the same day, the children participated in tasks designed to elicit visual and auditory event-related potentials, reported elsewhere (Hill and Steinhauser, 1993a; Steinhauser and Hill, 1993). Corrective glasses normally used by the subjects were worn during the procedures.

Visual stimuli were generated by an Atari 130XL computer and displayed on a Sakata SC-100 color monitor, with white stimuli on a black background. The subject’s head position was maintained 22.4 cm from the screen by a chin rest. Numbers and letters were 1.2 cm high and .8 cm wide (subtending respective visual angles of 3.1° and 2.1°). The subject sat in a dimly illuminated room. A technician sat behind the subject and corrected performance during practice trials.

**Continuous performance test.** The CPT involved presentation of single digits 0 through 9 for a duration of 50 msec at an interstimulus interval of 1,000 msec. Stimuli were blurred by placing a commercial rear projection screen onto the monitor screen. Background luminance was .2 cd/m^2^, with numbers producing a luminance ranging from 1.3-1.7 cd/m^2^.

The subject was instructed to press a button with the index finger of the preferred hand in response to appearances of the number “0” only, and not to the digits “1-9.” The subject was told to press quickly but accurately. A practice session of 162 trials was conducted, followed by a brief rest. Next, 486 test trials were presented. Each subset of 81 trials contained 20 zeros randomly following the other digits with roughly equal frequencies.

Reaction time (limited by the resolution of the Atari to the nearest 8 msec) was recorded for responses to all digits. The numbers of hits and false alarms were tabulated, and converted automatically into hit rates, false alarm rates, d’ level (sensitivity) and β (response criterion). The CPT data were analyzed with respect to total performance, as well as changes in performance over time.

**Span of apprehension.** Using the same display size as for the CPT, either 2, 6 or 10 letters were presented within a 9 × 9 character field (subtending visual angles of approximately 18° × 27°). The letters were not blurred. Background luminance was .5 cd/m^2^, with letters producing a luminance ranging from 4.0-6.7 cd/m^2^.

Changes in performance over time were not recorded in this procedure.

**Data analysis.** Data were analyzed by ANOVA (BMDP2V) according to risk status (high-risk or low-risk), gender (male vs female) and age (younger: 8-12 years; older: 13-18 years). Post hoc comparisons employed the Newman-Keuls Multiple Range Test (p < .05). In testing repeated levels of fixed factors (change within thirds of the session for d’ level, and numbers of distractors for the Span of Apprehension), the Greenhouse-Geisser correction for degrees of freedom was applied. Correlations among variables were also examined.
Results

Continuous Performance Test

CPT performance was not related to high- or low-risk status of the children tested. In contrast, effects of age and of gender were present. Mean values for measures of vigilance performance are provided in Table 1.

Sensitivity. There were no differences in visual sensitivity associated with either risk status or gender. Higher d' levels were observed for older than younger children \( (F = 19.5, 1/93 \text{ df}, p < .0001) \). The nonparametric estimate of sensitivity, A', was also calculated for comparison and produced similar findings for age effects \( (F = 12.9, 1/93 \text{ df}, p = .0005) \). Estimates of sensitivity using d' and A' were highly correlated across the entire sample \( (r = 0.95, p < .001) \).

Response criterion. Response criterion, \( \beta \), did not differ among groups according to risk status or age. However, girls showed higher levels of \( \beta \) than boys \( (F = 4.2, 1/93 \text{ df}, p < .044) \), indicating a significantly more cautious criterion for making responses.

Sensitivity decrement. Changes in sensitivity over time were examined by calculating d' levels for the three successive sets of 162 test trials. There were significant decreases in d' level during the session \( (F = 26.0, 2/174 \text{ df}, p < .0001) \), but no differences as a function of risk status.

The increase in d' level for older than younger children, noted above, was also observed in this analysis \( (F = 18.3, 1/93 \text{ df}, p < .0001) \). In contrast, response criterion \( (\beta) \) showed no significant changes over time.

Reaction times. Reaction times were significantly faster for male than for female subjects, both for hits \( (F = 5.8, 1/93 \text{ df}, p = .018) \) and for false alarms \( (F = 8.1, 1/93 \text{ df}, p < .0001) \). In the 1-distractor condition, boys performed with more errors than girls \( (F = 4.6, 1/93 \text{ df}, p = .04) \). No gender difference was observed for the 5- or 9-distractor conditions.

Span of Apprehension

All groups of children showed the typical pattern of significantly decreased performance accuracy as the number of distractors was increased \( (F = 206.7, 2/175 \text{ df}, p < .0001) \). Older children performed more accurately than younger children \( (F = 17.9, 1/93 \text{ df}, p = .0001) \). A Distractor \( \times \) Age interaction \( (F = 9.3, 2/175 \text{ df}, p = .0002) \) was due to significantly better performance for older than younger children for larger distractor set sizes than for single distractors.

Given a significant Group \( \times \) Gender \( \times \) Age \( \times \) Number of Distractors interaction \( (F = 6.8, 2/175 \text{ df}, p < .002) \), separate ANOVAs were conducted for each distractor set size.

In the 1-distractor condition, boys performed with more errors than girls \( (F = 4.6, 1/93 \text{ df}, p = .04) \). No gender difference was observed for the 5- or 9-distractor conditions.

Age was a significant factor on the larger set sizes. Younger children performed with significantly greater errors than older children in the 5-distractor condition \( (F = 21.5, 1/93 \text{ df}, p < .0001) \) and in the 9-distractor condition \( (F = 11.9, 1/93 \text{ df}, p = .0009) \).

There were no differences due to risk status on performance in the 1- and 5-distractor conditions. However, in the 9-distractor condition, an effect of risk status was seen in combination with gender and age \( (F = 4.8, 1/93 \text{ df}, p = .032) \). The older high-risk boys performed more poorly than their age-matched controls. All other groups showed increasing performance accuracy with age.

Power analyses indicated that effect sizes \( (Cohen, 1988) \) were small (ranging from \( D = .11 \) to \( .28 \)) among all groups.

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Table 1. Means (±SDs) for age and performance measures on the Continuous Performance Test and the Span of Apprehension. Subjects are grouped according to risk status, age group and gender.

<table>
<thead>
<tr>
<th></th>
<th>Young (8-12 years old)</th>
<th>Old (13-18 years old)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High-risk</td>
<td>Low-risk</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>N</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>Age (years)</td>
<td>9.4 ± 1.4</td>
<td>9.3 ± 1.6</td>
</tr>
<tr>
<td>Continuous Performance Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d'</td>
<td>1.00 ± .65</td>
<td>1.17 ± .79</td>
</tr>
<tr>
<td>A'</td>
<td>.75 ± .11</td>
<td>.75 ± .10</td>
</tr>
<tr>
<td>( \beta )</td>
<td>1.64 ± .66</td>
<td>4.98 ± 7.3</td>
</tr>
<tr>
<td>Hit rate</td>
<td>.48 ± .21</td>
<td>.42 ± 23</td>
</tr>
<tr>
<td>False alarm rate</td>
<td>.16 ± .07</td>
<td>.11 ± .09</td>
</tr>
<tr>
<td>Reaction time hits (msec)</td>
<td>533 ± 664</td>
<td>595 ± 83</td>
</tr>
<tr>
<td>False alarms (msec)</td>
<td>482 ± 55</td>
<td>499 ± 78</td>
</tr>
<tr>
<td>Span of Apprehension: No. correct out of 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOA-1*</td>
<td>37.5 ± 2.4</td>
<td>38.2 ± 1.4</td>
</tr>
<tr>
<td>SOA-5*</td>
<td>30.6 ± 3.2</td>
<td>31.4 ± 4.6</td>
</tr>
<tr>
<td>SOA-9*</td>
<td>28.8 ± 4.5</td>
<td>26.5 ± 4.2</td>
</tr>
</tbody>
</table>

*1-distractor condition; 5-distractor condition; 9-distractor condition; 1 case was missing.
for \( d' \). Also, for younger male and female groups, the power ranged from 3% to 17% for the most complex Span of Apprehension condition (9 distractors). Increasing sample sizes to 50 subjects per group would have increased power only to between 4% and 28%. A medium effect size was seen for the older female groups in the 9-distractor SOA \((D = .50, \text{ power } = 14\%)\). However, note that the high-risk girls performed better than the low-risk girls. The only large effect size seen was for older boys in the 9-distractor SOA \((D = 1.20, \text{ power } = 53\%)\), in which the high-risk boys performed more poorly than low-risk boys. For the latter comparison, increasing the size of each risk group to 12 subjects would increase power to 80%. Thus, we conclude that the pattern of findings is not likely to have been altered by larger sample sizes.

**Correlational analyses**

**Age-related changes.** On the CPT, increasing age was associated with higher levels of \( d' \) \((r = .49, p < .01)\) and faster reaction times to targets \((r = -.36, p < .01)\). On the SOA, there was little correlation between age and performance in the 1-distractor condition \((r = .09, \text{ ns})\), but there were significant improvements with age in the 5-distractor \((r = .51, p < .01)\) and 9-distractor \((r = .40, p < .01)\) conditions.

There was only one significant difference involving risk status associated with age: low-risk boys showed a strong association between age and increased performance on the 9-distractor SOA \((r = .60, p < .01)\). This differed significantly \((p < .05)\) from the lack of association for the high-risk boys \((r = -.05)\). Thus, high-risk boys showed less improvement in performance with maturation according to both the correlational and ANOVA-based analyses.

**Comparisons among tasks.** Across all subjects, \( d' \) level for the CPT was significantly correlated with \( \beta \) on the CPT \((r = .44, p < .01)\) and with improved performance on the SOA for 1, 5 and 9 distractors \((r = .35, .46 \text{ and } .50, \text{ respectively})\; \text{all } p < .01\). High- and low-risk groups did not differ on correlations of age or \( d' \) with any other variables.

**Discussion**

The present data indicate that children at high risk for alcoholism do not exhibit any impairments in sustained attention to visual stimuli as assessed by the Continuous Performance Test. Scanning and retrieval of information from iconic memory storage was impaired only for older \((13-18 \text{ years})\) high-risk boys when task demand was substantially increased on the 9-distractor version of the Span of Apprehension, but no differences were found between risk groups on the SOA when only 1 or 5 distractors were present. In separate studies of this same group of children in which event-related potentials were recorded, there were few performance errors, and no behavioral (reaction time) performance differences between groups by risk status, for tasks involving visual processing \((\text{Hill and Steinhauer, 1993a)}\) or auditory processing \((\text{Steinhauer and Hill, 1993)}\). In particular, the visual task, described earlier, required identification of target stimuli as well as utilization of specific information regarding head and ear orientation.

The similarity of vigilance performance in high- and low-risk children, as well as response criterion, on the degraded stimulus version of the CPT, suggests that no impairment of sustained vigilance is associated with high risk for the development of alcoholism. Differences in \( d' \) level were related only to changes in age.

Gender differences appear related to criteria for making a response. Girls were more cautious than boys, as indexed by higher levels of \( \beta \). The longer reaction times for girls than boys may also reflect a higher criterion for responding. Thus, the signal detection analysis provided a means for determining that apparent differences in performance due to gender were not related to differences in visual sensitivity.

Span of Apprehension performance indicated an interaction of risk status with gender and age group, but only for the largest distractor set size. Impaired performance was observed only for older high-risk boys compared to older low-risk boys. Girls showed more accurate performance than boys when there was only a single distractor. Older children showed increased accuracy when larger numbers of distractors were present, suggesting more efficient retrieval of information for older children.

In an initial report of auditory ERPs in high-risk children, we suggested that differences between high- and low-risk status were more likely to be observed as task complexity was increased \((\text{Hill et al., 1990)}\). The present findings for older high-risk boys on the Span of Apprehension are consistent with that notion, but cannot directly explain differences observed on ERPs in this same population. In the visual ERP paradigm, differences in P300 amplitude were observed primarily for the younger high-risk compared to low-risk boys, but not between the older boys \((\text{Hill and Steinhauer, 1993a)}\). Moreover, the visual ERP task required the discrimination of no more than two features, which could appear at only four known locations. The present iconic memory task involved a greater number of possible locations, and more distinct features even for a set size of 5 distractors, a level at which no differences due to risk status were observed.

Impairment of visual ERPs in children at high risk for alcoholism does not appear to be associated with sensory or perceptual deficiencies. The reason for employing these techniques with our high-risk children was to evaluate whether vigilance and iconic memory performance could provide a possible explanation for the decreased ERP amplitudes observed in children at high-risk for alcoholism, particularly younger boys, on visual tasks \((\text{Begleiter et al., 1984; Hill and Steinhauer, 1993a; Hill et al., 1995; Whipple et al., 1988)}\). No differences in sustained visual attention could be found for children at high risk for alcoholism. The efficiency of retrieval of information from iconic memory was not dif-
fent among high- and low-risk children, regardless of age or gender, when only a single or moderate number of distractors was present. However, impaired performance was seen among 13-18 year old high-risk boys when the greatest numbers of distractors were present. Differences in visual P300 between high- and low-risk children are typically not altered among the same children who displayed visual ERP decrements. Given the small effect size seen for d', it is clear that increasing sample sizes several fold would not have altered the present findings. These results strongly suggest that the decreased visual P300 amplitudes observed in children at high risk for alcoholism are the result of information-processing evaluation that occurs independently of perceptual and recognition phases.

Acknowledgments

The authors acknowledge the contributions of Timothy R. Smith, Ph.D., Lisa Lowers, M.A., Shawn Gronlund, M.B.A., Diane R. Muka, M.A., Susan Lainey, B.S., and many others, to various phases of this work. We are grateful to the children and their parents who through their participation and cooperation have contributed to this research program.

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