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RESEARCH LETTER

Impaired skill learning in children with heavy prenatal alcohol exposure

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INTRODUCTION

Global and widespread cognitive and behavioral dysfunctions have been documented in children with heavy prenatal alcohol exposure (CHPAE). In addition to further exploring explicit-memory functioning in this population, recent investigations have creatively looked into implicit-memory functions by testing the ability of CHPAE to perform priming (Mattson & Riley, 1999) or skill-learning (Carmichael Olson et al., 1998; Sampson et al., 1997) tasks. These empirical efforts have been supported by recent studies which have linked prenatal alcohol exposure to disproportionate volumetric reductions in subcortical structures such as the basal ganglia (Mattson et al., 1994) and cerebellum (Cavanagh et al., 1997), two structures that have been shown to be actively involved in implicit memory (Doyon et al., 1997, 1998; Heindel et al., 1989; Rauch et al., 1997). In each case, a profile of preserved implicit and impaired explicit-memory functioning has emerged. In the skill-learning domain, for example, participants were required to complete four blocks of 100 trials of the serial reaction time (SRT) task in which participants have to press the button which corresponds to the light that is illuminated, and in which there is an embedded sequence of ten positions that is repeatedly presented throughout blocks of trials. On the latter task, both studies indicated that CHPAE children tended to have longer mean response times than controls, but that their learning profile did not differ across the four blocks of trials.

Interestingly, deficits on skill-learning paradigms in clinical populations with damage to the striatum or cerebellum have been observed in the later stages of the acquisition process where the skill is thought to become automatic (Doyon et al., 1997, 1998; Karni, 1996) and not in the fast learning stage (i.e., first blocks of 100 trials). One must question whether four blocks of 100 trials is sufficient to tap into skill learning *per se*, a subcomponent of implicit memory that has been defined as habits that develop following extensive practice with a task (Anderson, 1990). Thus, this pilot study attempted to test the hypothesis that Carmichael Olson et al. (1998) and Sampson et al. (1997) did not find the CHPAE group to be impaired on the SRT task because the number of trials they administered was insufficient to examine the implicit learning of a visuomotor sequence.

METHODS

Participants

Two groups of participants were included in this study (see Table 1). They were aged between 8 and 14 years old and were fluent in English. Informed consent from parents or legal guardians were obtained and assent from the children was sought using an appropriate level of communication. This study was approved by the university's Ethics Review Board. The CHPAE group was composed of five children with a formal diagnosis of fetal alcohol syndrome/fetal alcohol effects. Each had a history of special education. A group of five control participants was selected to match the clinical group with regards to age and IQ. None of the controls had a positive history of special education or alcohol in the birth mother. All participants underwent a short battery of neuropsychological tests (see Table 1).

Materials

The SRT task was administered in the same fashion as Carmichael Olson et al. (1998) and Sampson et al. (1997). Participants were asked to press as quickly as possible the button corresponding to the light that is illuminated, while trying to make as few errors as possible. The stimulus remained

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Table 1. Participants' characteristics and results of the brief neuropsychological evaluation[a]

Variable/Group	CHPAE ($n = 5$) Mean (*SD*)	NC ($n = 5$) Mean (*SD*)
Age (years)	10.4 (1.8)	12.2 (1.8)
Education (years)	4.8 (1.3)	5.4 (1.5)
Full-Scale IQ (WISC-R)	82.7 (21.7)	89.4 (13.4)
Visual Span (WMS-III)	8.6 (3.4)[b]	15.4 (3.5)
CVLT-C Total	30.4 (11.0)	45.2 (12.4)
CVLT-C Long-Delay Free Recall	6.8 (2.8)[b]	12.6 (1.5)
Purdue Pegboard (Both Hands)	92.7 (19.5)	73.3 (15.6)

[a]CHPAE: Children with Heavy Prenatal Alcohol Exposure; NC: Normal Controls; WISC-R: Wechsler Intelligence Scale for Children—Revised; WMS-III: Wechsler Memory Scale—III; CVLT-C: California Verbal Learning Test for Children.
[b]$p < .05$.

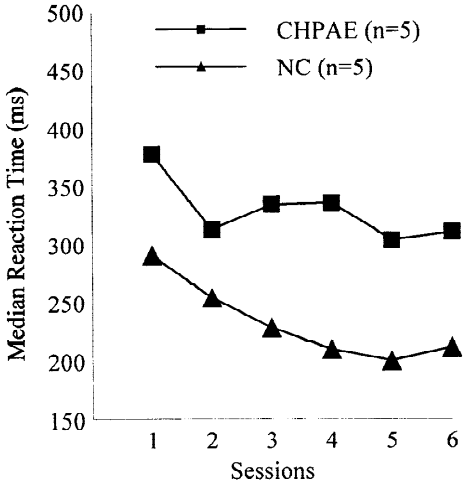

Fig. 1. Median reaction time (ms) for the CHPAE and NC groups on the serial reaction time (SRT) task across the six sessions of testing. Each session contained four blocks of 100 trials. The total number of trials administered was 2400.

displayed until the participant responded. After the participant's response, the light went off, and was followed 500 ms later by the display of another stimulus. In contrast to the methodology used by the above authors (who had administered four blocks of 100 trials), our participants completed six sessions, each session comprising four blocks of 100 trials (total = 2400 trials). The sessions were separated by 5-min pauses, while the blocks of trials within a session were administered 90 s apart.

RESULTS

Participants were well matched for age, IQ, education, and motor control. There was a significant difference in the Visual Span Total, $t(8) = -1.081$, $p < 0.05$. Results on the California Verbal Learning Test (CVLT-C) only revealed a difference in the Long Delay Free Recall Subtest, $t(8) = -4.101$, $p < .05$, hence suggesting that CHPAE did not remember as many words as the controls (i.e., 6.80 *vs.* 12.60) after a 20-min delay.

Results of the SRT task revealed that the groups did not significantly differ in their accuracy. Also, a choice reaction time task administered to see if our groups would differ in terms of motor speed *per se* revealed no significant differences between the groups. Congruent with the results of Carmichael Olson et al. (1998) and Sampson et al. (1997), analyses on the first session alone (i.e., the first four blocks of 100 trials) revealed a Block effect, $F(3,24) = 4.05$, $p < 0.05$, but no Group × Block Interaction. These results suggest that both CHPAE and normal controls (NC) were able to improve their performance from the first to the 400th trial, and that their learning profile did not differ early in testing. Consistent with our hypotheses, however, a 2 × 6 repeated measures ANOVA conducted on the six sessions of testing showed a significant Group × Session interaction, $F(5,40) = 2.60$, $p < 0.05$ (see Figure 1). This suggests that the groups indeed differed in their learning profile, particularly in the later stages of learning. Further correlational analyses conducted to determine whether the observed visuomotor skill-learning deficit in the CHPAE could be attributed to cognitive dysfunction or severity of motor symptoms (e.g., speed, motor control, and fatigue) revealed that the deficits could not be explained by these variables.

DISCUSSION

Results of this preliminary study replicate earlier findings of impaired explicit memory (Mattson & Riley, 1999) and intact implicit "fast learning" in CHPAE (Carmichael Olson et al., 1998; Sampson et al., 1997). However, they suggest that incremental skill learning, defined as the acquisition of a skill with extensive practice, may be impaired. This is consistent with current literature indicating a role for the striatum and cerebellum in the later stages of the acquisition process (Doyon et al., 1997, 1998), and provides further evidence for damage to these structures in prenatal exposure to alcohol. Future studies should attempt to replicate these findings with a larger number of participants and a variety of skill-learning tasks.

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