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Neurobehavioral Performance in Preschool Children from Agricultural and Non-Agricultural Communities in Oregon and North Carolina

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Abstract

Organophosphate (OP) pesticides produce acute toxic effects but little is known about low-level chronic exposures. Latino children of agricultural workers have a high risk of exposure to pesticides because of the close proximity of their homes to fields where pesticides are applied and from take-home exposure. Neurobehavioral performance of preschool children from agricultural (AG) communities was compared to performance of those from non-agricultural (Non-AG) communities in Oregon and North Carolina. Seventy-eight children aged 48–71 months completed a battery of neurobehavioral tests two times, approximately 1 month apart. Multiple regression revealed that the AG children performed poorer on measures of response speed (Finger Tapping) and latency (Match-to-Sample) compared to the Non-AG children. These results demonstrate modest differences in AG children compared to Non-AG children that are consistent with functional effects seen in adults exposed to low concentrations of OP pesticides. Just as was the case following early research on adults poisoned by pesticides, this study points to the need for additional investigations to test the hypothesis that low-concentration OP exposures affect acquisition of test performance, response speed and latency in children of agricultural workers.

Keywords: Neurobehavioral tests; Children; Agriculture; Latino; Hispanic

INTRODUCTION

Children can experience chronic low-concentration pesticide exposures that may cause effects not evident in routine clinical examinations (Landrigan, 2001). Children are particularly vulnerable to effects of pesticide exposure because of the rapid development of their organ systems and specific behaviors (e.g., increased time spent crawling and hand to mouth activity) that may increase their exposure (CDC, 2002; Cohen Hubal et al., 2000; Reed et al., 1999). Pesticide exposure can come from a variety of sources including diet, drinking water (Fenske et al., 2000; MacIntosh et al., 1996) and both indoor and outdoor residential use (Azaroff, 1999; Fenske et al., 2002; Lu et al., 2001).

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Children of agricultural workers are considered to have a higher risk of exposure to pesticides compared to the general population because of the close proximity of their homes to the fields where pesticides are applied and from take-home exposure (Azaroff, 1999; Coronado et al., 2004; Fenske et al., 2000; Lu et al., 2000; McCauley et al., 2001b; Quandt et al., 2004; Thompson et al., 2003). Research has shown detectable levels of pesticides in house dust (Bradman et al., 1997; McCauley et al., 2001a; Quandt et al., 2004; Simcox et al., 1995). Bradman et al. (1997) found that diazinon and chlorpyrifos house dust concentrations tended to be higher among farmworkers than non-farmworkers. Others have reported higher levels of pesticides in house dust in homes that are located closer to fields (Quandt et al., 2004) and in housing with larger numbers of farmworkers (Azaroff, 1999; Lu et al., 2000; McCauley et al., 2001b). In a sample of 24 homes of orchard and field workers, McCauley et al. (2001b) found detectable levels of azinphos-methyl in the majority of homes (19 out of 24). Other pesticides that were also detected included: chlorpyrifos, malathion, and phosmet. After-work hygiene practices have also been found to affect pesticide levels in the homes of farmworkers (McCauley et al., 2003).

Pesticides and Neurobehavioral Performance

Research examining neurobehavioral effects of pesticide exposure have focused primarily on acute effects in adult working populations. OP poisoned populations have shown a consistent pattern of deficits on measures of motor speed and coordination (Finger Tapping, Pursuit Aiming, Santa Ana Pegboard, Purdue Pegboard), sustained attention and information processing speed (Simple Reaction Time, Continuous Performance, Symbol-Digit) when compared to a non-exposed or non-poisoned population (Kamel and Hoppin, 2004; Reidy et al., 1992; Rosenstock et al., 1991; Savage et al., 1988; Steenland et al., 1994; Wesseling et al., 2002). Fewer studies have examined the effect of long-term, low-level exposure to pesticides on nervous system functioning. Neurobehavioral changes have been examined in different occupational groups chronically exposed to pesticides including sheep farmers (Stephens et al., 1995), greenhouse workers (Bazylewicz-Walczak et al., 1999), tree fruit workers (Fiedler et al., 1997), and farmworkers in Florida (Kamel et al., 2003). These studies have also found deficits in measures of sustained attention, information processing and motor speed and coordination (Simple Reaction Time, Symbol-Digit, Syntactic Reasoning, Pursuit Aiming). An examination of a highly exposed group of cotton pesticide applicators in Egypt found a broad range of deficits including visual motor speed, verbal abstraction, attention, and memory (Similarities, Digit Symbol, Trailmaking, Letter Cancellation, Digit Span, Benton Visual Retention) (Farahat et al., 2003).

Very little research has examined the effect of OP pesticides on children. Using versions of some of the same tests employed in the current study (Rohlman et al., 2001b), deficits on tests of cognitive functioning and reaction time were found in adolescents working in agriculture compared to adolescents not working in agriculture. Measuring growth and development (Guillette et al., 1998), differences in preschool children allegedly exposed to pesticides were found when compared to lesser exposed children. Although there were no differences in growth patterns, the exposed children showed deficits in hand-eye coordination, memory and ability to draw a person.

This paper describes the results of a study that compared neurobehavioral performance between young children from agricultural and non-agricultural communities. Specific research objectives were to compare the ability to learn test instructions and complete test components in Latino children from agricultural and non-agricultural communities and to compare the performance of children from agricultural and non-agricultural communities on specific measures of neurobehavioral performance.

METHODS

Setting

Children were recruited from agricultural regions in Oregon and North Carolina. In Oregon, the children were residing in Hood River County, a highly agricultural region of Oregon that produces tree fruit, primarily pears. Hood River is approximately 70 miles east of Portland. All children were recruited from Migrant Head Start facilities. The nature of agricultural work in this community and the degree of pesticide residues found in homes in this county has been previously described (McCauley et al., 2002, 2003). In North Carolina, the children were residing in a three county area in the eastern part of the state, including Johnston, Harnett, and Sampson Counties. This highly agricultural area produces primarily tobacco and vegetable crops such as cucumbers and sweet potatoes. The nature of work in this community has also been previously described (Arcury et al., 2001; Quandt et al., 1998).

The referent or non-agricultural community in Oregon was Lincoln County, a coastal community approximately 100 miles from Portland. Immigrant families in this community work primarily in the tourism and restaurant industry and children were recruited from a local community program, Centro de Ayuda. The referent community in North Carolina was Wilkes County in the western area of the state. Children were recruited from the community and Smart Start preschool program. The parents of these children worked in chicken processing plants, sawmills, and restaurants.

Participants

All children recruited for the study were Latino, ages 48–71 months, whose parents were immigrants to the United States. Study recruitment took place in the summer of 2002 in Oregon and summer of 2003 in North Carolina. This study was a community-based research project conducted with a difficult to access population of immigrant families. An effort was made to recruit every child referred by community members that met the study criteria. Any parent that was interested and met the criterion could have their child participate in the study. Children recruited from the agricultural communities had at least one parent working in agriculture at the time of the study. Neither parent of the children recruited from the non-agricultural communities had worked in agriculture in the previous year. Children of agricultural workers were recruited while their parents were working in agricultural crops. A bilingual research assistant explained the study and obtained informed consent from the parents. Parents completed a questionnaire on background characteristics such as age, education, years in the United States and work characteristics. Information on children's computer experience and video game use was also collected from parents in North Carolina. The children completed the neurobehavioral tests twice, approximately 4 weeks apart.

Neurobehavioral Testing

Neurobehavioral tests were administered individually to each child. The children completed the neurobehavioral battery two times approximately 4 weeks apart. Two test sessions were conducted because previous studies have shown learning or practice effects in adolescents and adults (Rohlman et al., 2000a, 2001b). The sessions allowed an examination of differences in learning between the agricultural and non-agricultural groups. Since the sample size was small, the second testing session also maximized the number of children completing the tests. The sessions occurred either in a mobile testing vehicle or in a room at the Head Start center or community center. The neurobehavioral battery consisted of five tests from the computerized Behavioral Assessment and Research System (BARS) and three non-computerized tests, Object Memory, Purdue Pegboard, and Visual Motor Integration (Rohlman et al., 2001a). The neurobehavioral tests and functions assessed are shown in Table 1.

The BARS was initially developed for use with a broad range of working populations having varied education levels and cultural backgrounds (Anger et al., 1996; Rohlman et al., 2003). Features of the BARS that enable this applicability include: simple language instructions broken down into basic concepts (step-by-step training with competency testing at each instruction step); a "smiling face" used to reinforce performance; and adjustable parameter settings (Rohlman et al., 1996). A durable response unit with nine response buttons is placed over a keyboard (Rohlman et al., 2003) to minimize the impact of working on a potentially intimidating device such as a computer keyboard. Use of the battery with children and specific descriptions of the tests have been previously discussed (Rohlman et al., 2000b, 2001a).

During each test session an examiner was present to read instructions, answer questions, and reinforce responding when necessary (Rohlman et al., 2000b, 2001a). Tokens were earned for correct performance on the BARS tests, and the tokens were exchanged for nickels (approximately $4) at the end of the test session.

Statistical Analysis

Neurobehavioral performance measures and demographic variables such as age and education were summarized using means and standard deviations; dichotomous or discrete multi-level data were summarized with proportions. Multiple regression was applied separately to each neurobehavioral test measure to test whether the average performance of AG children was lower than Non-AG children after controlling for the child's age and mother's education. *P*-values for these comparisons are all one-sided due to the directed nature of the hypothesis. This basic model was enlarged to examine potential effects related to location (Oregon or North Carolina), the child's gender, and the potential interactions of these two

Table 1
Description of neurobehavioral tests and functions measured in the battery administered to the agricultural children

Name of test	Function and description
BARS Digit Span	Memory and Attention • Spoken presentation of number sequences • Two chances at each span length
BARS Finger Tapping	Response Speed and Coordination • Right and left hand tested • Number of taps in 20 s duration
BARS Match-to-Sample	Visual Memory • 15 stimuli shown for 3 s • Choose from three choices • Delay between presentation and choice varies from 1 to 8 s
BARS Continuous Performance	Attention • 75 shapes shown rapidly, 30 targets • Pressed key when target (circle) was shown
BARS Divided Attention	Divided Attention • Tapped button while reciting nursery rhyme • Right and left hand tested
Object Memory Test	Recall and Recognition Memory • Shown 16 objects and asked to name • Immediate and delayed recall; recognition test
Purdue Pegboard	Dexterity • Number of small pegs placed in holes during 30 s • Right, left and both hand trials
Visual Motor Integration	Hand–eye coordination • Copied line drawings

factors with age and mother's education. The joint effect of interaction terms was tested using an extra sum-of-squares F-test (Netter et al., 1989) and was retained in the model if significant ($P < 0.10$). An exact unconditional test (McDonald et al., 1977) was used to test differences in the proportion of computer use between the two communities. Tests based on the F-statistic are always two-sided, and other tests lacking a pre-specified directional effect are indicated as two-sided in the text.

RESULTS

A total of 78 children participated in the study (Table 2). No significant age differences were observed among the four study groups. Females were over-represented in the Oregon agricultural sample. The education level of the mother was higher in both non-agricultural samples compared to mothers from both agricultural communities; however, the difference was only significant in the Oregon sample ($t(73) = -2.44$, two-sided P-value = 0.02). Given these observed differences among groups and previous research showing the impact of demographic variables on neurobehavioral performance (Anger et al., 1997), all analyses were adjusted for age, gender and maternal education.

Information about the presence of computer and video games in the home and the time the children

Table 2
Demographic characteristics (means and standard deviations) of the preschool children from agricultural (AG) and non-agricultural (Non-AG) communities in Oregon and North Carolina

	N	Age (months)	Female (%)	Mother's education
Oregon				
AG	20	58.0 (7.0)	60	7.2 (3.5)
Non-AG	14	60.5 (9.2)	29	9.6 (2.8)
North Carolina				
AG	23	57.3 (6.7)	48	7.2 (2.6)
Non-AG	21	59.0 (7.0)	38	8.1 (2.5)

spent using them was gathered from the parents in North Carolina. Approximately 16% of both the agricultural and non-agricultural children had a computer in the home and approximately 13% of the agricultural and 33% of the non-agricultural children had video games in the home. Although only a small number of parents reported having a computer in the home, 80% of the agricultural group and 47% of the non-agricultural group reported that the child used a computer at least once a month. The agricultural group was found to spend significantly more time using a computer than the non-agricultural group (exact test, two-sided P-value = 0.04).

Completion of Neurobehavioral Tests

To assess the ability of the children to learn the instructions of the tests in the neurobehavioral battery, the children completed the neurobehavioral battery two times approximately 4 weeks apart. We have previously reported learning or practice effects in adolescents and adults (Rohlman et al., 2000a, 2001b). An examination of the proportion of children completing each neurobehavioral test during Sessions 1 and 2 is shown in Table 3. During Session 1, the average proportion of tests completed was 81.9% for the agricultural children and 81.1% for the non-agricultural children. The average number of tests completed improved for both groups during Session 2 (85.7% for the agricultural children and 88.9% for the non-agricultural children).

A greater proportion of children from the non-agricultural group were able to complete all of the test components in Session 2 than the agricultural children. In the children from Oregon, the agricultural group showed improvement from Sessions 1 to 2 on only two of the tests, Divided Attention and Object Memory. However, the non-agricultural children in Oregon showed improvement from Sessions 1 to 2 on five of the tests, Digit Span, Match-to-Sample, Continuous Performance, Divided Attention, and Purdue Pegboard.

A closer examination of two tests revealed that specific components of the tests were not being completed by some of the children. For example, the majority of children were able to complete all components of the Object Memory and Purdue Pegboard tests. However, if children had difficulty with these tests it was with a specific component of the tests. Several children had no trouble with the recall portions of the Object Memory test but they had difficulty completing the Recognition part of the test. Similarly, several children were able to complete the right and left hand trials of the Purdue Pegboard tests but had difficulty with the trial using both hands. Since both these components, the Object Memory recognition test and the both hand trial of the Purdue Pegboard, are at the end of the test it is possible that motivation or attention may explain these results.

Children from both communities were unable to complete the Continuous Performance and Divided Attention tests during Session 1. Although more children were able to complete the Divided Attention test during the Session 2, the number completing the Continuous Performance test was actually lower. During Session 2 at least 20% of all children could not complete these tests, plus feedback from the examiners administering the tests also indicated that the children had trouble completing these tests. Given these observed difficulties, performance on the Continuous Performance and the Divided Attention Tests were omitted from all subsequent analyses.

Comparison of Performance of Agriculture Children and Non-Agriculture Children

Data from the second test session were used to examine performance differences between children

Table 3
Percentage of agricultural (AG) and non-agricultural (Non-AG) children from Oregon and North Carolina completing the tests at Sessions 1 and 2

Test	OR AG Time 1	OR AG Time 2	OR Non-AG Time 1	OR Non-AG Time 2	NC AG Time 1	NC AG Time 2	NC Non-AG Time 1	NC Non-AG Time 2
Digit Span	75	75	71	86	70	78	67	81
Match-to-Sample	80	80	79	93	91	91	86	90
Finger Tapping	100	100	100	100	96	100	100	100
Continuous Performance	55	55	64	79	65	65	57	52
Divided Attention	50	80	50	79	65	74	62	76
Object Memory	90	100	100	92	74	78	81	95
Purdue Pegboard	100	100	86	100	100	96	100	100
Visual Motor Intregation	100	100	100	100	100	100	95	100

Table 4
Standardized means (and standard errors) from Session 2 for (AG) and (Non-AG) children from Oregon and North Carolina adjusted for age and mother's education

	Oregon AG	Oregon Non-AG	North Carolina AG	North Carolina Non-AG
Digit Span	3.5 (0.17)	3.3 (0.22)	3.5 (0.15)	3.6 (0.16)
Match-to-Sample				
Number correct	9.2 (0.85)	8.7 (1.2)	8.4 (0.76)	7.8 (0.80)
Latency	6022 (444)	6321 (621)	6589 (399)	6059 (418)
Finger Tapping				
Number taps right	48.0 (2.1)	53.4 (3.1)	47.2 (2.0)	47.3 (2.1)
Number taps left	41.2 (1.8)	42.2 (2.7)	39.4 (1.7)	39.0 (1.8)
Object Memory				
Number items named	15.1 (0.31)	14.8 (0.45)	13.5 (0.30)	13.2 (0.30)
Immediate recall	7.7 (0.44)	5.6 (0.64)	6.3 (0.42)	5.8 (0.43)
Delayed recall	6.0 (0.54)	6.2 (0.78)	5.5 (0.51)	4.3 (0.52)
Recognition	14.0 (0.90)	11.5 (1.3)	15.5 (0.92)	12.5 (0.88)
Purdue Pegboard				
Number of pegs right	10.0 (0.36)	9.6 (0.52)	9.7 (0.34)	8.9 (0.34)
Number of pegs left	8.4 (0.35)	8.8 (0.51)	8.5 (0.33)	8.0 (0.34)
Number of pegs both	6.8 (0.33)	6.6 (0.48)	6.9 (0.31)	6.1 (0.32)
Visual Motor Intregation	9.6 (0.55)	10.7 (0.80)	9.7 (0.52)	9.3 (0.53)

of agricultural and non-agricultural communities in Oregon and North Carolina (Table 4).

Multiple regression was used to compare the performance of AG and Non-AG children, while controlling for differences in location (Oregon or North Carolina), the child's age and gender, and mother's education (Table 5). Because of interaction effects, gender was retained for the analysis of Finger Tapping (right hand) and Match-to-Sample (number correct and latency). No differences were observed on the majority of performance measures. Male AG children from Oregon performed significantly worse than the

Table 5
One-sided *P*-values showing neurobehavioral performance differences between AG and Non-AG children in Oregon (OR) and North Carolina (NC) at Session 2

	AG compared to Non-AG	AG compared to Non-AG by location		AG compared to Non-AG by location and sex			
		OR	NC	OR		NC	
				M	F	M	F
Digit Span	0.40						
Match-to-Sample							
Number correct				0.69	0.74	0.71	0.62
Latency				0.18	0.96	0.01	0.93
Finger Tapping							
Number taps right				0.02	0.66	0.23	0.77
Number taps left	0.59						
Object Memory							
Number items named		0.66	0.79				
Immediate recall	0.99						
Delayed recall	0.92						
Recognition	0.99						
Purdue Pegboard							
Number of pegs right	0.96						
Number of pegs left	0.73						
Number of pegs both	0.95						
Visual Motor Integration	0.65						

All analyses adjusted for child's age and mother's education (basic model), adjustments for location and sex were performed for certain items.

male Non-AG children on right hand Finger Tapping ($t(60) = -2.08$, one-sided P-value = 0.02). The male AG children from North Carolina had significantly longer latencies on the Match-to-Sample test ($t(51) = 2.47$, one-sided P-value = 0.01) than the male Non-AG children.

DISCUSSION

Deficits in Test Completion

Preschool children of Latino immigrant parents from agricultural and non-agricultural communities in Oregon and North Carolina completed neurobehavioral tests during two test sessions. More children were able to complete the neurobehavioral tests during the second session suggesting the influence of knowledge acquisition on test performance. Although percent completion improvements were seen in both the AG and Non-AG groups, the Non-AG group showed greater improvement. This difference was seen primarily in the Non-AG children from Oregon in which approximately 91% of the children were able to complete the test battery in the second session compared to 81% from the first session, compared to an improvement from 81 to 86% in the AG children from Oregon. The Non-AG children from Oregon also had mothers with more years of education than the other groups (9.6 years versus 7.2–8.1 years) (Mink et al., 2004).

Deficits in Test Performance

Eleven out of 13 measures showed no significant deficit in performance in the AG children compared to the Non-AG children. However, children from the AG group had significantly poorer performance on measures of response speed (Finger Tapping) and latency (Match-to-Sample) when controlling for gender and location. This finding has also been noted in studies of adults exposed to OP pesticides. Specifically, deficits on measures of motor speed and coordination, including latency and response speed measures, have been reported in OP poisoned populations tested after recovery (Reidy et al., 1992; Rosenstock et al., 1991; Savage et al., 1988; Steenland et al., 1994) and in different occupational workers chronically exposed to pesticides (Bazylewicz-Walczak et al., 1999; Kamel et al., 2003; Rohlman et al., 2001b; Stephens et al., 1995). The AG children performed better than the Non-AG children on some of the memory measures (Object Memory Test, recall and recognition). Although Benton Visual Retention and Paired Associates measures of memory have been used with adult populations exposed to OP pesticides, memory has not been specifically identified as showing impairments due to pesticide exposure (Kamel and Hoppin, 2004). Deficits in agricultural workers have been found on the Benton Visual Retention Test (Farahat et al., 2003; Rosenstock et al., 1991), however.

While the sample sizes of the study were small, they were sufficient to give 80% power to detect effect sizes ranging from 0.2 to 0.8 for 10 of the 13 tests and larger effects (1.1–1.8 in size) would have been detected with the same power for the remaining three tests. Additionally, the power was 79% (MTS latency in NC males) and 66% (Finger Tapping right hand in OR males) for the tests that indicated significant differences between agricultural and non-agricultural children.

Controlling for Confounding Variables

Several potential confounders were considered in the analysis of these results. Demographic variables such as age, education, and gender have been known to impact performance on neurobehavioral tests (e.g., Anger et al., 1997). These variables were controlled for in the analysis. Several of the neurobehavioral tests were administered on a computer which may also affect performance. Previous research found preschool children enrolled in Head Start who had access to a computer performed better on measures of school readiness and cognitive development (Li and Atkins, 2004). However, there was no relationship between frequency of use and visual or gross motor skills in these children. A survey on computer use completed by the parents of the children in North Carolina revealed a difference between agricultural and non-agricultural children. Although only a small number of parents reported having a computer in the home, the agricultural children were reported to spend significantly more time using a computer than the non-agricultural group. Because computer experience has been shown to impact performance on cognitive tests (Li and Atkins, 2004) it may offer an explanation why the agricultural children in North Carolina did not show more deficits in the current study. Because of the potential impact of this experience on test performance, it is recommended that it be considered in all future investigations.

Factors Possibly Influencing Findings

Several factors may explain the modest differences seen in this study. Children have had lower exposure than adults working in the field and the length of exposure may not yet be great enough to affect the AG group substantially. School experience may also affect how children performed on the tests. Most of the agricultural children in North Carolina and all of the agricultural children in Oregon were enrolled in the Migrant Head Start Program, whereas the majority of non-agricultural children were recruited from the community and not enrolled in school.

The decision to exclude the tests that children had the most difficulty completing may also have influenced these results. The Continuous Performance and Divided Attention tests were not included in the analysis because a significant number of children had difficulty completing these tests. The Continuous Performance test and other measures of sustained attention have revealed differences between exposed and non-exposed adults (Rosenstock et al., 1991; Steenland et al., 1994; Stephens et al., 1995). The age of the child has been known to influence a child's ability to complete a test (Amler and Gibertini, 1996; Rohlman et al., 2000b). These problems are not unique to BARS, the computerized battery used in the current study. The Pediatric Environmental Test Battery (PENTB) was developed by the Agency for Toxic Substance and Disease Registry (ATSDR) as a basic neurobehavioral battery (Amler and Gibertini, 1996). Performance based tests are included in the battery for children 4 years and older. The present study administered a battery that consisted of both computer and non-computerized tests. Some of the tests were selected from the PENTB, including the Divided Attention, Visual Motor Integration, Purdue Pegboard, and Finger Tapping tests. The Divided Attention and Finger Tapping were administered as part of the BARS. It is possible that modification of these tests for young children may improve performance, as was the case when animals were substituted for shapes in the Continuous Performance test (Altmann et al., 1997).

The design of the present study contrasts children of agricultural and non-agricultural workers, on the assumption that the latter are at greater risk for exposure to OP pesticides due to take-home pesticide exposures and the greater proximity of homes to agricultural fields. Chronic exposure due to parent's occupation and proximity to fields is assumed based on evidence of bringing pesticide exposures home from active agricultural areas (McCauley et al., 2001b, 2003; Quandt et al., 2004), but it was not documented in this study. Furthermore, even if the exposure occurs, deficits may not show up until later during school or adulthood. This is consistent with the more pronounced deficits seen in studies of adults (Rosenstock et al., 1991; Savage et al., 1988; Steenland et al., 1994). Additionally, it is known that OP pesticides are used residentially (Quandt et al., 2004), particularly in low quality housing characteristic of all of the immigrant communities. Therefore, the use of residential OP pesticides in both agricultural and non-agricultural groups may reduce the differences between groups that might result from agricultural pesticide use.

Summary of Results

The present study compared the neurobehavioral performance of preschool children of agricultural and non-agricultural workers. Performance improved when the children were tested a second time. The results demonstrated modest deficits in AG children compared to Non-AG children that are consistent with functional effects seen in adults exposed to low concentrations of OP pesticides and those from post-poisoning studies. As a number of potential confounders could have produced or masked differences between these groups, studies of other agricultural groups are needed to replicate the neurobehavioral deficits seen here before definitive conclusions can be drawn about effects of OPs in children of agricultural workers. These findings in preschool children are similar to early studies of adult populations examining acute exposure (Rosenstock et al., 1991; Savage et al., 1988; Steenland et al., 1994) which found few significant deficits in the exposed population. Subsequent papers replicated this finding in the adult population and expanded the literature examining the impact of OP pesticides on neurobehavioral performance. Just as was the case following the early research on adults poisoned by pesticides (Rosenstock et al., 1991; Savage et al., 1988; Steenland et al., 1994), this study thus suggests an hypothesis meriting additional testing: low-concentration OP exposures affect acquisition of test performance and response speed (Finger Tapping) and latency (Match-to-Sample) in children of agricultural workers.

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