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Learning ability as a function of practice: Does it apply to farmworkers?

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Abstract

Objective—Farmworkers experience significant work-related health risks including pesticide-associated cognitive impairment. Practice effect is a surrogate for learning ability. This study examined differences in cognitive function and learning capacity in Latino farmworkers and non-farmworkers.

Methods—Tasks of learning and short-term memory, executive function and working memory, perceptual coding, and psychomotor function were assessed at baseline and 3-month follow-up in 136 farmworkers and 116 non-farmworkers.

Results—Farmworkers had better performance on visuospatial learning and short-term memory at baseline ($p<0.05$). However, non-farmworkers showed more practice effects, or improvement on cognitive performance, at 3-month follow-up relative to farmworkers. Further, the amount of improvement on visuospatial learning ability, short-term visuospatial memory, and perceptual coding ability was significantly higher than farmworkers.

Conclusions—Practice effects may serve as an additional cognitive readout to differentiate healthy individuals from those with cognitive impairment.

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INTRODUCTION

Research has documented the occupational pesticide exposure of farmworkers. Most of these farmworkers are Latinos who are exposed to a wide variety of pesticides, including insecticides, fungicides, and herbicides.(1–5) Evidence continues to document the effects of pesticide exposure on health, including cancer, respiratory illness, and infertility.(6–9) Epidemiological studies document the association of Parkinson's disease with occupational exposure to pesticides.(10, 11) Adverse cognitive and other neurobehavioral findings have also been observed in individuals who are exposed to pesticides, although data on cognitive impairments are limited and inconclusive. Several studies have supported the hypothesis that broadly-defined pesticide exposure may increase risk of cognitive and psychomotor dysfunction,(12–15) but not all studies examining this relationship have reported an adverse effect.(16–20) Despite the inconclusive data, systematic reviews of neurotoxic studies suggested that pesticide exposure may be associated with deficits in cognitive function and neurodegenerative diseases.(21, 22) These studies have focused on organophosphorous insecticides because of their known neurotoxic mechanism that involves inhibiting acetylcholinesterase and the subsequent accumulation of synaptic acetylcholine in peripheral and central nervous systems.(23–26) Neurotoxic effects from other pesticides such as pyrethroid and carbamate insecticides have also been reported.(21) Based on these findings, one could infer that pesticide exposure may affect not only cognitive performance but learning as well. However, the relationship between pesticide exposure and learning potential has not been pursued in previous studies.

Practice effects, defined as improvements in cognitive test performance due to repeated administrations of the same test, have traditionally been viewed as sources of error. However, practice effects are considered an important cognitive readout because they represent a basic form of cognitive plasticity, reflecting learning potential.(27–31) Previous studies suggest that learning potential is a risk factor for cognitive impairment and that an absence of practice effects or short-term declines (i.e., negative practice effects) may indicate cognitive dysfunction.(28, 32) Additionally, practice effects have potential utility in the diagnosis of cognitive impairment, separating individuals with intact cognition from those with cognitive impairment. Individuals with intact cognition show robust retest learning effects, whereas those with memory and cognitive impairment exhibit low gains following repeated exposure to the tests.(33–36) Prognostically, short-term practice effects have been shown to predict longitudinal cognitive outcomes.(35, 37) The underlying mechanisms responsible for learning impairment remain to be determined, but cerebral changes produced with the onset of impairment is thought to explain the low plasticity in people with cognitive impairment.(38)

The current study examined differences in cognitive function and learning capacity between Latino farmworkers and non-farmwork Latino manual workers. Studies of pesticide exposure and cognitive function have often included tests that assess memory, attention, visuospatial processing, and other aspects of cognitive function. For the current study, we selected tests that are widely used and have been associated with pesticide exposure.(39) We also chose to focus on retest learning and practice effects that represent not only learning capability but also an additional important cognitive readout. To date, few comparisons of learning potential in farmworkers have been conducted. Thus, we addressed what we identified as possible gaps in previous works on breadth of neuropsychological performance. We hypothesized that current employment in agriculture would be associated with poorer cognitive function. We also examined differences on measures of new learning and memory, as well as changes in these measures and other cognitive tasks across a 3-month test-retest interval. We expected farmworkers to demonstrate lower learning and practice effects, as indicated by measures of new learning, short-term memory, and test-retest scores, than non-farmworkers.

METHODS

Participants

The data used in this analysis were collected in 2012 as part of an ongoing program addressing the health of Latino farmworkers and their families in eastern North Carolina. The study was based on a community-based participatory research approach with Latino communities to examine pesticides exposure and subclinical neurologic outcomes, including cognitive function.

Participants included Latino farmworkers and a comparison group of Latino non-farmworkers from two areas in North Carolina: farmworkers from the east central agricultural counties of Harnett, Johnston, and Sampson, and non-farmworkers from the west central Forsyth County, which contains the city of Winston-Salem.(40) All participants were men aged 30 to 70 who self-identified as Latino or Hispanic; almost all spoke Spanish as their primary language. Farmworkers had to be currently employed as agricultural laborers and to have worked in agriculture for at least three years. Non-farmworkers could not have been employed for the past 3 years in jobs that expose workers to pesticides, including farm work, forestry, landscaping, grounds keeping, lawn maintenance, and pest control. Potential farmworker and non-farmworker participants were excluded if they reported being told by a healthcare professional that they had diabetes.

Community partners assisted with recruitment. North Carolina Farmworkers Project (Benson, NC) staff approached the farmworker camps that they served, explained the project to the residents, and asked for volunteers. Volunteers were screened to ensure that they met the inclusion criteria. Wake Forest staff in Forsyth County worked with El Buen Pastor Latino Community Services and other community organizations to identify potential participants. Potential participants were contacted by project staff who explained the project, and asked if the individual wanted to volunteer. Volunteers were screened to ensure that they met the inclusion criteria. The Wake Forest School of Medicine Institutional Review Board approved the study protocol, and each participant provided written informed consent.

A total of 235 farmworkers and 212 non-farmworkers agreed to participate in the study. Of these, 210 farmworkers and 163 non-farmworkers completed the first data collection at which cognitive function data were collected; 136 farmworkers and 116 non-farmworkers completed the follow-up cognitive function tests 3 months later. This analysis is limited to the participants who completed the 3 month follow-up.

Farmworkers were asked to volunteer in groups; only the number who agreed to volunteer is available (the denominator is not known); generally, all of the farmworkers in a camp who met the inclusion criteria volunteered. However, individual farmworkers who did not want to participate could have avoided contact with the project staff or may have indicated that they did not meet the inclusion criteria to avoid refusal. Among the non-farmworkers, 101 individuals were contacted who did not meet the inclusion criteria. Of those contacted and meeting the inclusion criteria, 87 individuals refused to participate for a participation rate of 70.9% (212/(87+212)). Reasons given for refusing included the time commitment and length of the study (51), blood draws (27), need to come to a clinic for data collection (31), and providing contact information (30) (individuals could give more than one reason for refusing).

Farmworkers recruited to the project were all migrants; most (92.8%) had H-2A visas. During the course of the agricultural season, they were largely involved in the planting, cultivation, and harvesting of tobacco. Non-farmworkers were settled immigrants who worked in a variety of industries, including construction (43.4%), manufacturing (16.0%), maintenance (8.5%), food preparation and service (6.6%), sales (6.6%), auto repair (6.1%), and transportation (4.2%).

Data Collection

Farmworker participants completed data collection from May through September, and non-farmworkers completed data collection from June through October. Participants completed an initial questionnaire, generally in the camp (farmworkers) or home or location such as a community center (non-farmworkers). The questionnaire contained demographic and health items, including chronic conditions and depressive symptoms. The questionnaire was developed in English and translated into Spanish. When possible, existing Spanish items were used. The Spanish and English versions were checked for comparable meaning for each item, and item wording was adjusted as needed. The Spanish version of the questionnaire was pre-tested with several native Spanish speakers, and final corrections were made. Interviewers included native Spanish speakers who completed training that addressed questionnaire content and proper technique for conducting interviews.

Cognitive function was assessed at baseline and at 3-month follow-up. A battery of cognitive tests was conducted in a clinic setting and in a private room by a trained and certified administrator. The battery consisted of three verbal and three non-verbal tests that were chosen based on the WHO Neurobehavioral Core Test Battery.(41) The selected tests included audio- and visuo-tasks, geometric shapes, and numbers so that they were culturally neutral and could be administered to non-English speaking and low literacy individuals. The final sample in these analyses included 136 farmworkers and 116 non-farmworkers that had complete cognitive function data at both baseline and 3-month follow-up.

Measures of Cognitive Function

Six widely used cognitive function tests were selected to tap several cognitive domains, including learning and short-term memory, executive function and working memory, perceptual coding, and psychomotor function. Learning and short-term memory were assessed using the Hopkins Verbal Learning Test–Revised (HVLT) and the Brief Visual Memory Test–Revised (BVMT). The HVLT assesses verbal learning and short-term verbal memory with a list of 12 nouns (targets) with four words drawn from each of three semantic categories.(42) The list is presented across three consecutive trials with immediate free recall. A 20- to 25-minute delayed free recall trial is also administered to assess short-term verbal memory (HVLT-Delay). The BVMT assesses visuospatial learning and short-term visuospatial memory.(43) Participants are presented with a stimulus page depicting six geometric figures. The page is exposed for 10 seconds. Immediately after its removal, participants attempt to draw as many of the figures as possible in their correct location on a page in the response booklet. The BVMT is administered similar to the HVLT across three consecutive trials with immediate free recall. A delayed recall trial is administered after a 20- to 25-minute delay (BVMT-Delay). In this study, we focused on widely used HVLT and BVMT measures of learning and memory. For both measures, total free recall for trial 1 assesses initial recall; the two subsequent presentations (trials 2 and 3) are posed as learning. Total recall summed across trials 1 through 3 provides an estimate of verbal learning ability (HVLT) or visuospatial learning ability (BVMT). Total free short-delay recall assesses short-term verbal memory (HVLT-Delay) or short-term visuospatial memory (BVMT-Delay). Alternate test forms of HVLT and BVMT were used during retesting.

Executive function, operationally defined here as working memory, cognitive flexibility, and response inhibition abilities, was estimated by Digit Span Forward (DSF), Digit Span Backward (DSB),(44) and Letter Alteration Task.(45) In Digit Span, the examiner reads a series of numbers. After the full series is read, the participant repeats them in the order in which they are given (Forward) or repeats them in the reverse order of presentation (Backward). Scores for DSF and DSB can range from 0 to 14. The Letter Alteration Task draws on cognitive skills such as cognitive flexibility and response inhibition. It consists of two rows of letters “A” and “B” in random order. The task consists of two trials. For the Letter Reading (LR) trial, participants read two rows of letters just as they appear on a stimulus card. During the Letter Alteration (LA) trial, participants read the opposite letter of that which is pictured on the same stimulus card. Scores for LR and LA are based on the time to complete each trial.

The Digit Symbol Test (DST)assesses perceptual coding ability.(44) Participants are given a series of numbered symbols and then ask to draw the appropriate symbols below a list of random numbers. The score is based on the number of correct matches in two minutes.

The Grooved Pegboard (GP) assesses psychomotor coordination and dexterity.(46) The test consists of 25 holes with randomly positioned slots. Each peg has a ridge on one side that must be rotated to match the hole on the pegboard before the peg can be inserted. The score is the length of time to complete the task with the dominant hand.

Covariates

We adjusted the analyses for established confounders including age and education. Depression was assessed with a 10-item version of the Center for Epidemiologic Studies Depression (CES-D) scale assessing depressive symptoms in the past week.(47) A standard cutoff score of 10 has been reported as indicative of significant depressive symptoms.(48)

Self-reported medical conditions were assessed by asking participants if they had ever been told by a doctor that they had heart disease or high blood pressure.

Statistical Analyses

Chi-square tests were used to compare the distributions of variables between farmworkers and non-farmworkers. We performed a series of analyses for each of the cognitive tests. The changes in cognitive test scores were compared within farmworkers and non-farmworkers separately by within subject comparisons using the paired t-tests. The mean differences and standard error of the differences are presented. Differences between the farmworkers and non-farmworkers, and changes over the agricultural season were determined by comparing between group differences using analysis of covariance adjusted for the preselected, established confounders of age, education, depressive symptoms, heart disease status, and high blood pressure status. No variable selection technique was used.

RESULTS

Table 1 shows the baseline characteristics of farmworkers and non-farmworkers. The two groups differed on age and education, but they were comparable for depressive symptoms, heart disease, and high blood pressure. Farmworkers were younger compared with non-farmworkers. Farmworkers had a mean age of 39.2 years; 38% were between the ages of 30–34. Non-farmworkers had a mean age of 41.9 years; 28% were between the ages of 30–34. Farmworkers had lower education attainment, with 40% having 6 or fewer years.

Table 2 compares the cognitive scores of farmworkers with non-farmworkers, after adjusting for confounders. Cognitive scores were generally similar for both groups at the baseline assessment. Farmworkers performed significantly above non-farmworkers on the visuospatial learning (BVMT, $p=0.02$) and short-term memory measures (HVLT-Delay, $p=0.01$ and BVMT-Delay, $p< 0.01$) at the baseline assessment. However, these differences were not observed at the 3-month follow-up assessment. Further, non-farmworkers performed better than farmworkers on the executive function and working memory measure DSF ($p=0.05$) and the perceptual coding measure DST ($p=0.06$) at the second assessment.

Table 3 shows changes in cognitive function between baseline and 3-month follow-up. In general, both groups performed significantly better at 3-month follow-up than at baseline. While farmworkers showed significant improvements on four out of ten tests, non-farmworkers demonstrated significantly more practice effects or improvements on nearly all tests, even though the two groups were generally comparable at baseline testing. Further, the amount of improvement on visuospatial learning ability (BVMT, $p=0.01$), short-term visuospatial memory (BVMT-Delay, $p=0.01$), and perceptual coding ability (DST, $p=0.04$) was significantly higher in non-farmworkers than farmworkers, adjusted for confounders. It should be noted that while non-farmworkers significantly improved on the BVMT-Delay, farmworkers showed a non-significant, but decline on the short-term visuospatial memory test.

DISCUSSION

In this study, we compared the cognitive function of Latino farmworkers with non-farmworker Latino manual workers. We hypothesized that current employment in agriculture would be associated with poorer cognitive function. Contrary to our expectations, we found that the farmworker group had better performance on visuospatial learning and short-term memory at baseline, and no significant difference between the two groups on other cognitive tests. These findings conflict with other studies where pesticide exposure has been associated with lower cognitive function.(12–15) The discrepancies between our findings and other studies could be due to many factors, including subject populations, occupation (e.g., pesticide applicators), the specific cognitive tests used, insensitivity of cognitive tests to potential impairments, and the possibility that some of the non-farmwork Latino manual workers might be exposed to pesticides that occur from dietary and or other environmental and occupational sources.(49, 50) Further, the farmworkers, most of whom migrate to North Carolina each year with H-2A visas, may reflect a pronounced healthy worker effect in which individuals with any impairment do not return. Another possibility for the discrepancy between our findings and those from the existing literature is exposure assessment. Studies with more detailed exposure assessments or quantitative exposure measures have generally found an association of pesticide exposure with neurologic dysfunction and disease,(21) but not all studies assessing quantitative exposures reported adverse effects.(17, 19) Our current analyses did not consider biomarkers of exposure assessment. We used agricultural status as a nonspecific indicator of pesticide exposure and this may result in exposure misclassification. However, our previous analysis has shown that the two groups do represent very different exposure histories.(40) Further, our approach is the basis of the Agricultural Health Study, which has provided extension information on the association of pesticide exposure and neurologic outcomes among farmers.(14)

The results from the 3-month test-retest data showed differences between the groups in regards to practice effects in cognitive performance. The non-farmworker group showed a practice effect on eight out of ten tests. These performance gains were observed for the learning and short-term memory, executive function and working memory, and perceptual coding domains. The finding of significant practice effects is consistent with existing studies that have shown that practice effects occur, most prominently in tests of learning and memory and executive function, when repeated assessments are conducted within a brief period of time.(51, 52)

Our study also revealed practice effects on four out of ten measures in the farmworker group. Farmworkers showed improvements in verbal learning ability, short-term verbal memory, visuospatial learning ability, and perceptual coding ability. These results indicate that farmworkers do maintain learning capacity, although they in effect require a larger number of successive trials and the amount they learn depends on more frequent rehearsal and retrieval than non-farmworkers. The lower learning ability among farmworkers may arise from many factors, including education level. Previous studies have recognized the relationship between higher education attainment and higher practice effects,(53, 54) and the challenge to disentangle the effects of education from cognitive function on practice effects.(55, 56) We attempted to address this issue by adjusting for education level in our analyses.

An important way in which the farmworker group differed from the non-farmworker group was the pattern of performance in memory abilities. We noted that the non-farmworker group performed above farmworkers on the working memory measure DSF at baseline and at 3-month follow-up. Further, while non-farmworkers significantly improved on the BVMT-Delay, farmworkers showed no improvement on the delayed memory task and on the contrary, declined slightly on the test. Memory is often considered part of the learning process, because it represents an essential step for storing and retrieving information that is learned.(57) As memory is essential to all learning, the reduced memory capacity observed in farmworkers may limit the learning ability.

Our work was based on a growing body of research on cognitive plasticity, also conceptualized as learning ability. Within the framework of cognitive plasticity, the literature seems to suggest robust learning effects in healthy individuals, but those impaired also exhibit a certain capacity for learning.(33–36) Further, the concept of cognitive plasticity is particularly useful in studies that have used practice effects to detect individuals at-risk of impairment or early cognitive impairment.(28, 35, 58) We observed practice effects in both farmworkers and non-farmworkers, but retest learning was clearly lower in the farmworker group. Though initial cognitive performances remain to be the best indicator of current ability, practice effects may significantly contribute unique information. The unique contribution of practice effects may be particularly salient in pesticide-exposed individuals where some impairment is expected. Neurotoxic studies have suggested that pesticide exposures, particularly organophosphorous insecticides, inhibit acetylcholinesterase and the subsequent accumulation of synaptic acetylcholine in peripheral and central nervous systems.(23–26) With central nervous system limitations, farmworkers may demonstrate less learning capacity whereas non-farmworkers, due to the functional integrity of their neurologic systems, may be able to learn adequately. Nonetheless, the effect of pesticide exposure on neurobehavioral function including learning capacity is still unclear. Further investigation is needed in order to consolidate these data and also to identify and elucidate the mechanisms by which pesticides may act to disrupt neurologic function.

This study has several limitations. We did not include other measures (e.g., Stroop Task) of cognitive function that may be sensitive to cognitive impairments. We selected tests that were culturally neutral and could be administered to non-English speaking and low literacy individuals. Even with these tests, significant differences in learning and memory were observed. Our analyses included only those with complete cognitive data at baseline and 3-month follow-up. This resulted in a sample size that was relatively small. However, no learning effect would have been found if only the results of the farmworker group were considered. The inclusion of the non-farmworker group was essential for us to determine the potential effect of pesticide exposure on cognitive function as indicated by learning capacity. Although our data support our hypothesis regarding current employment in agriculture and learning ability, other explanations may be possible. For example, the low practice effects observed in farmworkers may reflect factors other than cognitive plasticity or learning. Factors such as participant fatigue or test anxiety has been reported.(59)

In summary, the current study extends the literature on neurobehavioral function in farmworkers by addressing practice effects, reflecting the capability of an individual to learn and adjust. If these findings can be replicated in other samples, practice effects have the potential to serve as an additional cognitive readout to differentiate healthy individuals from those with cognitive impairment.

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Table 1

Baseline participant Characteristics, n=253.

	Farmworkers (n=136)		Non-farmworkers (n=116)		
Participant Characteristics	**n**	**%**	**n**	**%**	**P-value**
Age					
30 to 34 years	51	38	32	28	0.06
35 to 44 years	51	38	40	34	
45 years and older	34	5	44	38	
Education					
0 to 6 years	55	40	37	2	< 0.001
7 to 11 years	67	49	39	34	
12 or more years	14	10	40	34	
Depressive Symptoms (CES-D ≥ 10)	10	7	7	6	0.68
Heart disease (yes)	1	1	3	3	0.24
Hypertension (yes)	19	14	12	10	0.38

Table 2

Differences in cognitive function between farmworkers and non-farmworkers

	Baseline cognitive function			3-month follow-up cognitive function		
	Farmworkers	Non-farmworkers		Farmworkers	Non-farmworkers	
Cognitive Function[a]	Mean ± SE	Mean ± SE	P-value[b]	Mean ± SE	Mean ± SE	P-value[b]
HVLT	21.39 ± 0.30	20.61 ± 0.34	0.09	22.33 ± 0.35	21.82 ± 0.38	0.32
HVLT-Delay	7.28 ± 0.16	6.62 ± 0.18	0.01	7.77 ± 0.18	7.41 ± 0.20	0.18
BVMT	16.61 ± 0.43	15.58 ± 0.40	0.02	18.60 ± 0.55	17.90 ± 0.51	0.20
BVMT-Delay	6.95 ± 0.18	5.57 ± 0.21	< 0.01	6.77 ± 0.19	6.49 ± 0.20	0.32
DSF	6.13 ± 0.11	6.42 ± 0.12	0.07	6.42 ± 0.15	6.86 ± 0.16	0.05
DSB	6.04 ± 0.12	6.06 ± 0.14	0.85	6.12 ± 0.15	6.19 ± 0.16	0.74
LR	17.82 ± 0.51	17.94 ± 0.57	0.88	17.25 ± 0.34	16.50 ± 0.37	0.20
LA	29.64 ± 0.65	31.32 ± 0.74	0.09	29.00 ± 0.78	28.66 ± 0.85	0.77
DST	40.62 ± 0.83	40.50 ± 0.94	0.92	43.47 ± 1.12	46.54 ± 1.21	0.06
GP	72.73 ± 1.19	75.46 ± 1.36	0.13	70.37 ± 1.21	72.29 ± 1.31	0.29

[a]Abbreviations used in Table 2: HVLT, Hopkins Verbal Learning Test; BVMT, Brief Visual Memory Test; DSF, Digit Span Forward; DSB, Digit Span Backward; LR, Letter Reading; LA, Letter Alteration; DST, Digit Symbol Test; GP, Grooved Peg.

[b]Models were adjusted for age, education, depressive symptoms, heart disease status, and high blood pressure status.

Table 3

Differences between farmworkers and non-farmworkers in the amount of changes in cognitive function

	Change in cognitive scores between baseline and 3-month follow-up				Difference in the change of farmworkers and non-farmworkers	
	Farmworker		Non-farmworker			
Cognitive Function[a]	Δ mean ± SD	P-value	Δ mean ± SD	P-value	Difference Δ	P-value[b]
HVLT	0.97 ± 0.39	0.01	1.20 ± 0.42	0.01	−0.23 ± 0.58	0.69
HVLT-Delay	0.56 ± 0.23	0.02	0.72 ± 0.25	0.01	−0.17 ± 0.34	0.63
BVMT	1.73 ± 0.55	0.01	2.05 ± 0.50	<0.001	−0.32 ± 0.40	0.01
BVMT-Delay	−0.10 ± 0.21	0.64	0.82 ± 0.23	< 0.01	−0.91 ± 0.32	0.01
DSF	0.20 ± 0.13	0.12	0.32 ± 0.14	0.02	−0.11 ± 0.19	0.56
DSB	0.15 ± 0.14	0.30	0.08 ± 0.15	0.58	0.06 ± 0.21	0.76
LR	−0.39 ± 0.71	0.58	−1.62 ± 0.76	0.03	1.23 ± 1.07	0.25
LA	−0.39 ± 0.67	0.55	−2.04 ± 0.72	0.01	1.65 ± 1.00	0.10
DST	2.95 ± 0.70	< 0.01	5.08 ± 0.75	< 0.01	−2.13 ± 1.04	0.04
GP	−1.89 ± 1.18	0.11	−0.82 ± 1.27	0.52	−1.07 ± 1.76	0.55

[a] Abbreviations used in Table 2: HVLT, Hopkins Verbal Learning Test; BVMT, Brief Visual Memory Test; DSF, Digit Span Forward; DSB, Digit Span Backward; LR, Letter Reading; LA, Letter Alteration; DST, Digit Symbol Test; GP, Grooved Peg.

[b] Models were adjusted for age, education, depressive symptoms, heart disease status, and high blood pressure status.