Neurobehavioral Effects of Organic Solvents Exposure Among Wood Furniture Makers in Ile-Ife, Osun State, Southwestern Nigeria

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Background. Furniture making industries are small scale businesses that commonly use organic solvents. There has been minimal focus on the health effects of this chemical hazard on the nervous system among furniture makers in Nigeria.
Objectives. The present study aimed to assess the association between organic solvents exposure and neurobehavioral status of furniture makers, using electronic technicians as a comparison group.
Methods. A comparative cross-sectional study design was employed. A sample size of 108 was calculated for each group. A semi-structured interviewer-administered questionnaire was used to obtain data on the socio-demographic variables and use of personal protective equipment (PPE). A proforma was developed to collect neurobehavioral assessment data. A checklist was used to assess the furniture makers' workshops. Air was sampled from all of the workshops in both the study and comparison groups to determine the concentration of total volatile organic compounds (TVOCs).
Results. The use of PPE was poor in both the study and comparison groups, with no significant difference between them (34.4% and 37.7% respectively). Total volatile organic compound and formaldehyde (HCHO) concentrations were significantly higher at the furniture makers' workshops compared with electronic technicians ($p<0.001$) for both chemicals. The 8-hour time-weighted average of TVOC was also higher in the furniture makers' workshops (4.4 ± 0.6 mg/m^3) compared with the control group (0.3 ± 0.3 mg/m^3). The neurobehavioral symptoms score was significantly higher among the study group relative to the comparison group ($p<0.001$). There was a significant difference in the outcome of the auditory verbal learning test, total recall ($p=0.005$), and delayed recall ($p=0.003$). There was no significant association between solvent exposure index and findings from the simple reaction time test
Conclusions. Poor compliance with the use of PPE among furniture makers may increase their exposure to organic solvents. There were more neurobehavioral changes in the furniture makers with a higher exposure index. Measures are needed to educate artisans about work-related chemical hazards and ensure compliance with basic occupational safety and hygiene standards.
Participant Consent. Obtained
Ethics Approval. Ethics approval was obtained from the Health Research and Ethics Committee of the Institute of Public Health, Obafemi Awolowo University (IPH/OAU/12/1049).
Competing Interests. The authors declare no competing financial interests.
Keywords. organic solvents, volatile organic compounds, neurobehavioral effect, furniture makers
Received December 31, 2018. Accepted April 4, 2019.
J Health Pollution 22: (190604) 2019

Introduction

Organic solvents are common chemicals used in wood furniture manufacturing to modify the pigments and resins in paint for ease of application on surfaces being prepared for painting.[1,2] The solvents help reduce the viscosity of paints.[2] Many of these solvents are heavily laden with volatile organic compounds (VOC) which have been shown to be a risk factor for various diseases, hence the need for a multi-dimensional approach to limiting exposure, such as setting exposure limits and advocacy for adoption of standard practices such as the use of personal protective equipment.[3,4] Common VOCs that have been identified in the furniture-making industry include acetone, butane-2-one, ethyl, isobutyl and methoxy propyl acetate, 4-methylpentan-2-on, toluene, ethylbenzene, and xylenes.[5]

The degree of exposure to VOCs varies across work practices.[6,7] For example, spraying in a confined space with poor ventilation increases the dose of exposure.[7] Painting method also has an effect on exposure dose. The use of brushes and rollers is associated with lower exposure compared with the use of spray guns, which is a common practice in most wood furniture workshops.[6] Some furniture makers also make use of cheaper alternatives to the standard spray gun, using appliances such as hand-held mist sprayers which do not require electricity or gasoline for power. These improvised tools are able to convert paint into mist, like the spray gun, but with a lower dose of exposure.

Volatile organic compounds cause various health effects which can be broadly classified into acute and chronic. These can be due to acute high dose exposure to the organic solvents or chronic low dose exposure.[3] Most paint solvents are lipid soluble, hence their ability to cause neurotoxicity, as lipids are major components of both the central and peripheral nervous systems.[3] Neurologic symptoms associated with acute high dose exposure include headaches, nausea, vomiting, dizziness, and fainting, while the effects associated with long-term exposure may include headaches, confusion, disorientation, behavior change and memory impairment, as well as numbness and weakness in the extremities.[3] These symptoms were the commonly reported symptoms in the self-reported neurobehavioural symptoms survey among workers of paint factory in Nigeria with headache being the most reported symptom.[16] Neurologic and behavioral changes among those exposed to organic solvents have been documented in previous studies.[8-14] Neurobehavioral assessments are conducted using test batteries which could either be computer-based or paper-based.[15] These tests include the simple reaction time test (SRT), digit symbol substitution test (DSST), finger tapping speed, line tracing, and the auditory verbal learning test (total recall and delayed recall).[15]

Many studies have documented an association between exposure to volatile organic compounds and derangement in the outcome of most of these neurobehavioral assessment tests.[9,10,13] Some previous studies also demonstrated a dose-response relationship between volatile organic compound exposure and the outcome of neurobehavioral assessment tests.[10,12,13,17,18] In addition, a meta-analysis of studies on the impact of solvent mixtures on neurobehavioral performance showed negative overall effects among the exposed individuals with significant derangements in tests of attention and motor function.[18]

Most studies on neurobehavioral effects of VOC exposures have been conducted in developed countries where working conditions and enforcement of safety regulations differ from the majority of African countries. Neurobehavioral effects of organic solvents among Nigerian artisans have been largely under-studied. Studies are therefore needed to determine the level of organic solvents exposure among furniture makers and to assess the neurobehavioral effects of this exposure. The present study aimed to assess the association between organic solvents exposure and neurobehavioral status of furniture makers, using electronic technicians as a comparison group. The study results were communicated to individual participants immediately after completion of the tests, and to members of the artisan associations during their meetings. This was done based on the request of the leaders of the Association of Furniture Makers and Carpenters, and the Electronic Workers' Association at the inception of this study.

Abbreviations

AVLT	Auditory verbal learning test	*PPE*	Personal protective equipment
DSST	Digit symbol substitution test	*SRT*	Simple reaction time

Methods

The present study was conducted in Ile-Ife, an ancient town located in Osun State, southwestern Nigeria. The town has two local government areas, Ife Central and Ife East, with a population of 167,254 and 188,027, respectively, according to the 2006 national population census.[19] Most of the furniture makers in Ile-Ife operate in open spaces or locations within residential areas. Furniture makers carry out their work in open areas or in makeshift sheds, as there are no specialized spraying booths. This exposes workers and nearby residents to associated occupational hazards. Both furniture makers and electronic technicians are organized under well-structured associations: the Association of Furniture Makers and Carpenters, and the Electronic Workers' Association, respectively.

There are very few industries in the town, but many small and medium scale enterprises exist such as sachet water factories and sawmills. There are no formal occupational health services

for artisans, nor any formal health notification or compensation systems. Consequently, there is little data available on occupational accidents and diseases arising from hazardous working conditions.

Study design and population

The present study was conducted using a comparative cross-sectional study design, with furniture makers as the study group and electronic technicians serving as the control group. All participants in the present study were male, as both vocations (furniture making and electronics repair) are male-dominated and there were no women on the registers of either association in the study area at the time. Data were collected over three months between June and August 2018 (during the rainy season).

The study was approved by the Health Research and Ethics Committee of the Institute of Public Health, Obafemi Awolowo University (IPH/OAU/12/1049).

Sample size and sampling technique

A sample size of 108 was included for enrollment in each group, study and comparison using Equation 1.

Equation 1

N/per group = 2 σ2 (Zα+Zβ)2 / difference

where N/per group is the minimum sample size per group, Zα is the standard normal deviation of α at 95% confidence level (1.96), Zβ is the standard normal deviate of β at 80% confidence level (0.84), the difference is the mean difference in forced expiratory volume between the two groups that the investigator is willing to accept (0.1 liters), and σ is the standard deviation of the forced expiratory volume in the first second (FEV1) (i.e. the pooled estimate of the standard deviation in the two groups is 0.25 L as extrapolated from findings in the study by Ojo et al.).[20]

The N/per group = 2 x 0.25^2 $(1.96 + 0.84)^2$ / $(0.1)^2$, N/per group = 98. The correction for anticipated attrition = n/1-10% and therefore the adjusted sample size was 108 in both groups, furniture makers and electronic technicians.

Study participants were selected through a multistage sampling technique. Both groups of artisans are participants of associations that organize as zonal units based on geographical location. There are 12 zonal units for furniture makers and 14 zones for electronic technicians in Ile-Ife.

The selection process included three stages. In stage 1, six zonal units were selected through a simple random sampling and balloting technique from each artisanal group. In stage 2, workshops were selected using a systematic random sampling technique from the list of registered workshops in each zone. Finally, in stage 3, at the selected workshop, a master and an apprentice were recruited. Where there was no apprentice, more than one apprentice was selected from the next workshop with more than one apprentice using a simple random sampling and balloting technique.

The comparison group (electronic technicians) were also selected using the same technique. The comparison group was matched by age with the study group. Neurobehavioral assessment tests were administered to all participants and ambient air assessment of total volatile organic compounds (TVOCs) was conducted in all of the selected workshops.

Data collection

Data were collected using a semi-structured interviewer-administered questionnaire, a checklist for workshop assessment, and various neurobehavioral symptoms tools (Android phone-based and paper-based). The questionnaire can be found in Supplemental Material. The questionnaires were administered by community health officers who were trained on the content before commencement of data collection. The neurobehavioral assessments were conducted by trained medical doctors employed as research assistants. Verbal and written informed consent was obtained from all participants.

The questionnaire assessed the sociodemographic status of the respondents, knowledge of organic solvents-related health hazards, and safety measures. The questionnaire also assessed work practices of the respondents, including assessment of commonly used chemicals, frequency of usage, cumulative period of use, and means of application of chemicals to finished products. Other sections in the questionnaire addressed the pattern of personal protective equipment (PPE) use, factors affecting usage of PPE, and history of smoking and substance abuse. The use of PPE was classified into regular, occasional and never use. The PPE that were being used daily or when they are required were classified as regular use while those that were being used when the worker felt like wearing them were classified as occasional use. The PPE that workers have never used in their practice were classified as never used.

The neurobehavioral symptom inventory in the questionnaire was adapted from the US military health system.[21] This tool assessed the perceived neurobehavioral symptoms and rated perceived symptoms based on

severity. Severity was rated from none (scored 0) to very severe (scored 4).

Workshop inspections were conducted using a checklist. The checklist was developed to assess factors that may influence solvent exposure, such as the structure of the workshop in terms of ventilation, type of spray gun used for spray painting, inspection of available PPE, sanitation, and hygiene facilities, including organic solvent disposal methods.

Neurobehavioral assessment

Psychometric tests were conducted using a battery of tests to assess concentration, motor speed, and visuospatial control. The tests were conducted between 8 and 9 am, before the work day, and were administered by resident physicians who were trained on the application of the tools. The tests were carried out within the participants' workshop in a comfortable space with minimal distraction. The assessments included several tests described below.

The line tracing test (trail drawing test) involved making a trace on a 5 mm wide path without touching the borders, working as fast as possible. The time to complete the task was noted and each participant had three attempts. The average score from the three attempts was calculated.[15,22]

The serial dotting test is a simple test requiring a pencil and paper. Participants were instructed to place a dot at the center of circles on either side of a parallel line as fast as possible within 10 seconds. The number of dots placed was counted at the end of 10 seconds. The average score from three attempts was calculated.[15,22]

The digit symbol substitution test requires the substitution of digits with symbols. The number of substitutions the participant was able to make within 90 seconds was recorded. Each participant had three trials. The average score from three attempts was calculated.

Memory tests were conducted in two phases in the form of the auditory verbal learning test (AVLT) total recall and auditory verbal learning test delayed recall (AVLT delayed).[15] The AVLT total recall test was conducted by presenting fifteen common household items and places the participants were familiar with. Participants recalled the objects at a regular interval of 5 minutes on three different occasions. Participants were reminded of the objects they forgot after each recall attempt. The number of items recalled correctly was documented. Participants had one mark for each correct answer.

The AVLT delayed recall test included the same list of items used in the AVLT total recall test. Participants were asked to produce the items on the list at a minimum of 20 minutes after the third trial of AVLT total recall. Before asking the participants to recall the list the items were not recited to the participants as in the AVLT total recall. The number of items recalled correctly was documented. Participants received one mark for each correct answer.

The simple reaction time test was conducted using Android phone-based software. The software was based on color change which occurred at unpredictable intervals. Participants were instructed to touch the green spot at the center of the application display as soon as it changed to red. The application allows 5 trials per participant. It records the duration taken for the participants to respond to changes in color in milliseconds.[15,22]

The finger tapping test was conducted on the dominant hand using Android-based software, "Finger Tap Fit Test" (Computer service Moritz Pfaff, Germany). The device was placed on a flat horizontal surface while the participants tapped the software with the index finger of the dominant hand as fast as possible within 10 seconds. The number of taps within 10 seconds was recorded and each participant had three trials.[15,22]

Assessment of ambient air concentrations of organic solvents

A DM106A air quality monitor was used to assess the TVOC concentration and formaldehyde (HCHO) concentrations (Langder Technology Co.,Ltd, Guangdong China). The DM106A is a handheld device which samples the air through diffusion collection and detects VOCs through semiconductor technology. It has a detection range of 0.000-9.999 mg/m^3 for TVOC and detection range of 0.000-1.999 mg/m^3 for HCHO. The device also has the capacity to assess particulate matter ($PM_{1.0}$, $PM_{2.5}$, PM_{10}), temperature, and humidity.

The device was calibrated according to the manufacturer's instructions every day before the commencement of air sampling. The device was used to assess the ambient air concentration of VOCs while the respondents sprayed their finished products and while the comparison group was performing routine electronic repair activities in their workshops. The device was held close to the breathing zone while sampling the air in the workshops. The device takes the first reading of TVOC and HCHO after the first five minutes. The readings were taken at an interval of five minutes and six readings were observed over a 30-minute period. The average of the six readings was used to estimate the 8-hour time-weighted average. The exposure index was calculated using the formula derived by Fidler et al. in a study conducted among painters and allied professions.[23]

Variables	Furniture makers N (%)	Electronic technicians N (%)	Statistics
Level of education			
No formal education	2 (2.1)	1 (1.0)	LR= 2.082
Primary	42 (43.3)	37 (36.3)	df= 3
Secondary	42 (43.3)	54 (52.9)	p= 0.555
Post-secondary	11 (11.3)	10 (9.8)	
Alcohol consumption			
Never	45 (49.5)	60 (59.4)	$\chi 2$= 2.994
Rarely	14 (15.4)	9 (8.9)	df= 3
Sometimes	22 (24.2)	20 (19.8)	p= 0.393
Frequently	10 (11.0)	12 (11.9)	
Smoking status			
Current smoker n (%)	0 (0.0)	0 (0.0)	$\chi 2$=0.546
Ex-smoker n (%)	7 (7.8)	10 (9.8)	df= 1
Non-smoker n (%)	94 (92.2)	92 (90.2)	p= 0.460
Age (mean ± SD), years*	38.2± 13.9	37.37 ±12	0.650
Years of work experience* (mean ± SD)	19.0 ±15.4	13.6± 9.9	0.004
Average monthly income* (mean ± SD)	26561.0± 18607.1	14212.3± 18607.1	0.648

Abbreviations: LR, likelihood ratio; df, degree of freedom; x^2, Chi Square * T-test.

Table 1 — Socio-Demographic Variables

Number of PPE used Regularly	Furniture makers n (%)	Electronic technicians n (%)	Statistics
0	61 (65.6)	67 (66.3)	
1	13 (14.0)	19 (18.8)	
2	10 (10.8)	11 (10.9)	LR= 7.016
3	3 (3.2)	3 (3.0)	df= 6
4	2 (2.2)	1 (1.0)	p= 0.319
5	3 (3.2)	0 (0.0)	
6	0 (0.0)	0 (0.0)	
7	1 (1.1)	0 (0.0)	
8	0 (0.0)	0 (0.0)	

Table 2 — Comparison of Personal Protective Equipment Use Across Study Groups

Data analysis

Data were analyzed using SPSS version 22 (IBM SPSS Inc., Chicago, USA). The median and inter-quartile range was used to summarize continuous variables such as ambient air concentration of VOC and HCHO. Categorical variables were summarized using frequencies and proportions. Eight PPE items that could be used by the workers were identified. The items are: safety boots, waterproof apron, safety goggles, hand gloves, nose mask, respirators with air filters, face shield and headcover. Total number of PPE being used on a daily basis out of the eight PPE was assessed and compared using Chi square. The Mann Whitney U test[24] was used to compare associations between workshop air quality in the workshops of furniture makers and electronic technicians due to skewness of the data. The Mann Whitney U test was also used to test for significance of differences between the two groups in terms of neurobehavioral symptom score, neurobehavioral assessment findings, and to assess the association between the exposure index and neurobehavioral assessment findings. Quantile regression analysis was used to assess the determinants of the various neurobehavioral assessment findings due to skewness of the data. A p-value of <0.05 was considered to be statistically significant.

Results

In all, 102 furniture makers and 101 electronic technicians participated and completed the survey, with a completion rate of over 95% in both artisan groups. Five percent of the respondents had incomplete data and were removed from the study. There was no significant difference between the furniture makers and the comparison group in terms of age, level of education, ethnicity, religion, and marital status. The socio-demographic variables are shown in Table 1.

The use of PPE was poor in both groups. The majority of the respondents in both the study and comparison groups used no PPE in their practice, 65.6% and 66.3%, respectively. There was no significant difference in the use of PPE among furniture makers and electronic technicians (p= 0.319).

The parameters assessed during air

quality monitoring included particulate matter, TVOC, HCHO, temperature, and humidity. All of the parameters were higher in the workshops of furniture makers than in the workshops of electronic technicians (p<0.001) with the exception of temperature, which was significantly higher in the electronic technicians' workshops, and HCHO, which was higher in the furniture makers' workshops, although this difference was not statistically significant (p=0.067). The average room temperature for the furniture makers and electronic technicians was 24.3°C and 27.3°C, respectively.

The 8-hour time-weighted average concentration of TVOC was statistically significantly higher in the furniture maker workshops (n= 61, mean= 4.4±0.6 mg/m^3) compared to the control group workshops (n=68, mean= 0.3±0.3 mg/m^3, p<0.001).

The neurobehavioral symptom score based on self-reported neurological and behavioral symptoms was statistically significantly higher among furniture makers (n= 99, median = 4.0, IQR= 7.0) compared to electronic technicians (n= 101, median= 3.4, IQR= 5.2) (U= 3482.5, df= 198, p<0.001).

A total of 202 participants (101 furniture makers and 101 comparison groups) underwent neurobehavioral assessment. The mean score for the AVLT total recall among the furniture makers was 7.0±2.1, while the mean score for the electronic technicians was 6.1±1.9. The difference between these means was statistically significant (p=0.005). The difference in median score on the AVLT delayed recall between the furniture makers (median= 6.0, IQR= 5.0) and the electronic technicians (median= 5.0, IQR= 3.0) was also statistically significant (p=0.003). The median duration for line tracing was higher among the furniture makers (median=

Characteristics	Furniture makers n=61 median (IQR)	Electronic technicians n=68 median (IQR)	U value	Degree of freedom	p value
$PM_{2.5}$ (µg/m^3)	554.3 (289.8)	23.0 (14.9)	185.0	127	p<0.001
$PM_{1.0}$ (µg/m^3)	377.8 (277.4)	18.6 (11.5)	161.0	127	p<0.001
PM_{10} (µg/m^3)	555.0 (412.2)	26.7 (16.1)	176.5	127	p<0.001
HCHO (mg/m^3)	2.0 (0.1)	0.07 (0.05)	259.0	127	p<0.001
TVOC (mg/m^3)	9.99 (0.0)	0.49 (0.36)	48.0	127	p<0.001
Temperature (°C)	24.3 (1.3)	27.3 (2.8)	914.0	127	p<0.001
Humidity (%)	80.1 (2.7)	67.8 (6.6)	832.5		p<0.001

Abbreviations: IQR, interquartile range; PM, particulate matter.

Table 3 — Comparison of Workshop Air Quality

Characteristics	Furniture makers' workshops n= 61 (mean ± SD)	Electronic technicians' workshop n=68 (mean ± SD)	T value	Degree of freedom	p value
TVOC in (mg/m^3) (8-hour time-weighted average)	4.4±0.6	0.3±0.3	-59.1	127	**p<0.001**

Abbreviation: SD, standard deviation.

Table 4 — Comparison of 8-Hour Time-Weighted Average of Total Volatile Organic Compounds

Characteristics	Furniture makers n=101 median (IQR)	Electronic technicians n=101 median (IQR)	U value	Degree of freedom	p value
Line tracing	32.7 (16.8)	26.7 (18.1)	4249.5	198	p= 0.067
Serial dotting	27.3 (12.2)	26.8 (10.3)	4947.0	199	p= 0.803
DSST	29.7 (13.0)	32.0 (10.8)	4426.0	194	p=0.349
SRT	0.5 (0.5)	0.6 (0.5)	4685	200	p= 0.318
Finger tapping (dominant hand)	57.7 (12.9)	56.0 (14.6)	4683.5	196	p= 0.591
AVLT total recall	7.0±2.1	6.1±1.9	-2.848*	194	p= 0.005
AVLT delayed recall	6.0 (5.0)	5.0 (3.0)	3079.0	180	p= 0.003
Neurobehavioral symptom score	4.0 (7.0)	1.0 (6.0)	3482.5	198	**p<0.001**

* = T-test.

Abbreviation: IQR, interquartile range.

Table 5 — Neurobehavioural Assessment Findings

Characteristics	Low exposure index median (IQR)	High exposure index median (IQR)	U value	Degree of freedom	p value
Line Tracing	30.0 (21.0)	32.8 (16.9)	1194.0	97	p= 0.834
Serial dotting	28.0 (9.3)	25.7 (13.4)	1000.5	98	p= 0.088
DSST	31.7 (10.3)	28.5 (15.4)	920.0	93	p=0.123
SRT	0.5 (0.3)	0.5 (0.7)	1125.0	98	p= 0.391
Finger tapping (dominant hand)	58.7 (10.7)	56.5 (14.2)	986.0	98	p= 0.069
AVLT total recall	7.7 (2.7)	6.7 (2.5)	969.0	93	p= 0.238
AVLT delayed recall	7.0 (4.0)	6.0 (5.0)	766.5	86	p= 0.090

Abbreviation: IQR, interquartile range.

Table 6 — Association Between Exposure Index and Neurobehavioral Assessments of Furniture Makers

Variables	B	P-value	95% CI
PPE use			
Regular	1.03	0.672	-3.77 to 5.84
Occasionally	-0.50	0.842	-5.45 to 4.45
Exposure index	-0.14	0.400	-0.45 to 0.18
Age	-0.29	0.035	-0.57 to -0.02
Level of education			
Primary	-1.29	0.810	-11.87 to 9.29
Secondary	0.15	0.978	-10.43 to 10.73
Tertiary	3.20	0.602	-8.90 to 15.30
Year of experience	0.23	0.146	-0.08 to 0.54

Abbreviations: B, regression coefficient.

Table 7 — Quantile Regression of Association Between Respondents' Characteristics and Finger Tapping Test Among Furniture Makers

Variables	B	P-value	95% CI
PPE use			
Regular	0.22	0.680	-0.85 to 1.30
Occasionally	0.64	0.252	-0.46 to 1.75
Exposure index	-0.03	0.392	-0.10 to 0.04
Age	-0.04	0.202	-0.00 to 0.02
Level of education			
Primary	-0.81	0.495	-3.16 to 1.53
Secondary	0.55	0.644	-1.79 to 2.89
Tertiary	0.42	0.755	-2.26 to 3.10
Year of experience	0.02	0.541	-0.05 to 0.09

Abbreviations: B, regression coefficient.

Table 8 — Quantile Regression of Association Between Participant Characteristics and Auditory Verbal Learning Total Recall Among Furniture Makers

32.7, IQR= 16.8) compared with the median duration among the electronic technicians (median= 26.7, IQR= 18.1). The difference in line tracing results, was not statistically significant. The differences in the mean values for all of the neurobehavioral assessments are shown in Table 5.

In the comparison of exposure index with neurobehavioral assessment outcomes, SRT was found to be almost equal in those high exposure index and those with low exposure index. (median= 0.5 IQR=0.7) and (median= 0.5, IQR=0.3) respectively.

The mean value of taps in the finger tapping test of the dominant hand was lower in those with a high exposure index (median= 58.7, IQR= 10.7) compared with furniture makers with a low exposure index (median= 56.5, IQR= 14.2). The association between the difference in these mean values and exposure index was statistically significant. Although the mean values for serial dotting, DSST, and AVLT (total and delayed recall) were higher among furniture makers with a low exposure index, the difference was not statistically significant.

Participant age was an important determinant on the finger tapping test. A unit increase in age reduced the number of taps by 0.29 [β= -0.29, (95% CI, -0.57 to -0.02) p= 0.035]. Although an increase in solvent-exposure index also reduced the number of taps, this was not statistically significant.

The quantile regression analysis of the association between respondents' characteristics and AVLT total recall is shown in Table 8. There was no significant association between the respondents' characteristics and outcome of AVLT total recall.

The quantile regression analysis of the association between respondents'

characteristics and AVLT delayed recall is shown in Table 9. Occasional use of PPE, exposure index, age and years of experience were significantly associated with outcome of AVLT delayed recall. An increase in exposure index reduced the number of items recalled [β= -0.08, (95% CI, -0.16 to -0.003) p= 0.042]. In addition, a unit increase in age was associated with a reduction in the number of items recalled by 0.07 [β= -0.07 (95% CI, -0.13 to -0.01) p= 0.027]. However, a unit increase in the year of experience increased the item recall by 0.10 [β= 0.10, (95% CI, 0.03 to 0.17) p= 0.007].

Variables	B	P-value	95% CI
PPE use			
Regular	0.27	0.634	-0.85 to 1.39
Occasionally	1.28	0.027	0.15 to 2.41
Exposure index	-0.08	0.042	-0.16 to -0.003
Age	-0.07	0.027	-0.13 to -0.01
Level of education			
Primary	0.13	0.913	-2.21 to 2.47
Secondary	0.66	0.579	-1.67 to 2.99
Tertiary	1.54	0.266	-1.18 to 4.25
Year of experience	0.10	0.007	0.03 to 0.17

Abbreviation: B = regression coefficient

Table 9 — Quantile Regression of Association between Participant Characteristics and Auditory Verbal Learning Delayed Recall among Furniture Makers

Discussion

The neurobehavioral symptom score was found to be significantly higher among the furniture makers compared with the electronic technicians. This difference could be attributed to greater exposure to VOCs because there was no significant difference in age and level of education, which has been previously observed to affect neurobehavioral status. The neurobehavioral assessments revealed mild changes in relation to the degree of exposure. The median simple reaction time was equal across groups. The average finger tapping rate was also found to be significantly lower among those with a high exposure index. These findings were in agreement with similar studies that reported a dose-response relationship between exposure to VOCs and development of neurobehavioral signs.[10,12,13,17]

There was no significant difference in most of the neurobehavioral assessments conducted in the study and comparison groups, with the exception of AVLT total and delay recall. Electronic technicians recalled fewer of the listed items during immediate total recall and delayed recall. This may be due to chronic low dose exposure of lead used for soldering, as lead is known to cause memory impairment among other forms of neurobehavioral disorders.[25] Although the results of the other tests were not statistically significant, it took furniture makers a longer time on average to complete the line tracing task and electronic technicians were able to complete a greater number of substitutions on the DSST. These findings are in contrast to those in a study conducted among Libyan child workers exposed to organic solvents where there was a significant association between exposure to organic solvents and outcomes on the DSST and SRT.[13] The findings are also in contrast to results in studies among American painters and Korean shipyard spray painters where a significant association between organic solvent exposure and DSST was reported.[10,17] The study among the Korean shipyard sprayers also revealed a significant relationship between occupational exposure to organic solvents and other neurobehavioral tests such as the SRT test and finger tapping speed.[10] Variations in study outcomes could be due to differences in work practices and work environment such as spraying in a confined space, which was uncommon among the population in the present study.

Occasional use of PPE was found to be significantly associated with the development of memory impairment. The majority of furniture makers who used PPE only used a surgical face mask as an improvised nose cover. Surgical face masks do not meet the specifications for face masks required for spray painting. The use of a surgical face mask may confer a false sense of security and lead to prolonged exposure to organic solvents. The use of inappropriate PPE coupled with non-regular use of PPE among the majority of the participants may increase their risk of adverse effects of organic solvent exposure and neurobehavioral effects.

The exposure index was observed to be lower than observations in previous studies.[5,6,10,18] The lower exposure index found in the present study could be attributed to factors in the work practice of furniture makers which are key factors in the mathematical model used for the exposure index calculation. These include spraying in an open space instead of confined spraying booths. This allows room for natural ventilation to dilute atomized organic solvents under natural conditions. In addition, the frequency of painting was found to be low among the

studied furniture makers due to low patronage and limited availability of jobs requiring spraying. The volume of the organic solvents used also varies with the size of the finished item and make-shift spraying devices releasing smaller volumes of mist were often used, which may have contributed to the lower exposure index among furniture makers. Despite the low exposure index, furniture makers still experienced derangements in neurobehavioral assessments which were greater among those with a higher exposure index. This may be attributed to chronic low dose exposure to organic solvents.

There are a few limitations to the present study. The use of other methods of exposure assessment such as biomarkers may have been more appropriate, but this would have been logistically difficult. The use of personal gas samplers to assess the organic solvent exposure of each artisan is preferable, however the equipment was not accessible nor were there laboratories available for sample analysis. Despite these limitations, the use of hand-held gas samplers provided a fair estimate of ambient air concentration of organic solvents across the artisanal workshops. In addition, all of the participants in the present study were male because the chosen professions are socio-culturally regarded as male professions in the study area. There may be a need for gender consideration in future studies.

Conclusions

Spray painting is a hazardous procedure which exposes furniture makers to high concentrations of organic solvents. Poor compliance with and disregard for basic occupational safety measures such as correct and consistent use of PPE may increase their risk of organic solvent exposure and associated neurobehavioral effects. Although the practice of spray painting in an open space may reduce artisans' exposure through natural ventilation, it inadvertently exposes their immediate environment and nearby residents to organic solvents. There is, therefore, a need to ensure compliance with standard operating procedures by the furniture makers through advocacy to their union leaders and worker education. Occupational health service units should be established at the local government level to ensure compliance with basic occupational safety procedures and workshops should be located away from residential areas to help mitigate the health effects of long-term exposure to organic solvents.

Acknowledgements
This study was funded as a part of employment.

References

1. **Reducing solvent use in the furniture industry.** United Kingdom: Environmental Technology Best Practice Programme; 1999 Mar. 48 p.
2. **Clark MD. Paints and pigments** [Internet]. Johnsonville, New Zealand: New Zealand Institute of Chemistry; [2017?] [cited 2018 Aug 9]. 19 p. Available from: https://www.nzic.org.nz/app/uploads/2017/10/10D.pdf
3. **Rutchik JS, Ramachandran TS.** Organic solvent neurotoxicity [Internet]. New York, NY: Medscape; [updated 2018 Dec 11; cited 2018 Jul 9]. Available from: https://emedicine.medscape.com/article/1174981-overview
4. **Spray painting and powder coating: code of practice 2013.** Queensland, Australia: Workplace Health and Safety Queensland; 2013 Dec 1. 40 p.
5. **Posniak M, Kowalska J, Makhniashvili I.** [Exposure to hazardous chemical substances in furniture industry]. Med Pr. 2005;56(6):461-5. Polish.
6. **Qian H, Fiedler N, Moore DF, Weisel CP.** Occupational exposure to organic solvents during bridge painting. Ann Occup Hyg [Internet]. 2010 Jun [cited 2019 Apr 4];54(4):417-26. Available from: https://doi.org/10.1093/annhyg/meq021
7. **Park H, Park HD, Jang JK.** Exposure characteristics of construction painters to organic solvents. Saf Health Work [Internet]. 2016 Mar [cited 2019 Apr 4];7(1):63-71. Available from: https://doi.org/10.1016/j.shaw.2015.10.004
8. **Berr C, Vercambre MN, Bonenfant S, Manoux AS, Zins M, Goldberg M.** Occupational exposure to solvents and cognitive performance in the GAZEL cohort: preliminary results. Dement Geriatr Cogn Disord [Internet]. 2010 [cited 2019 Apr 4];30(1):12-9. Available from: https://doi.org/10.1159/000315498
9. **Dick F, Semple S, Osborne A, Soutar A, Seaton A, Cherrie JW, Walker LG, Haites N.** Organic solvent exposure, genes, and risk of neuropsychological impairment. QJM. 2002 Jun;95(6):379-87.
10. **Lee CR, Jeong KS, Kim Y, Yoo CI, Lee JH, Choi YH.** Neurobehavioral changes of shipyard painters exposed to mixed organic solvents. Ind Health [Internet]. 2005 Apr [cited 2019 Apr 4];43(2):320-6. Available from: https://doi.org/10.2486/indhealth.43.320
11. **Nasanen R, Kaukiainen A, Hero V, Paallysaho J, Muller K, Hari R, Akila R, Sainio M.** Effects of long-term occupational solvent exposure on contrast sensitivity and performance in visual search. Environ Toxicol Pharmacol [Internet]. 2005 May [cited 2019 Apr 4];19(3):497-504. Available from: https://doi.org/10.1016/j.etap.2004.12.013 Subscription required to view.
12. **Sabbath EL, Glymour MM, Berr C, Singh-Manoux A, Zins M, Goldberg M, Berkman LF.** Occupational solvent exposure and cognition: does the association vary by level of education? Neurology [Internet]. 2012 May 29 [cited 2019 Apr 4];78(22):1754-60. Available from: https://doi.org/10.1212/WNL.0b013e3182583098 Subscription required to view.
13. **Saddik B, Williamson A, Black D, Nuwayhid I.** Neurobehavioral impairment in children occupationally exposed to mixed organic solvents. Neurotox [Internet]. 2009 Nov [cited 2019 Apr 4];30(6):1166-71. Available from: https://doi.org/10.1016/j.neuro.2009.08.003 Subscription required to view.
14. **Sainio MA.** Neurotoxicity of solvents. In: Lotti M,

Bleecker ML, editors. Handbook of clinical neurology. Vol. 131. Amsterdam, Netherlands: Elsevier B.V.; 2015. Chapter 7

15. **Anger WK. Education: neurobehavioural tests and systems to assess neurotoxic exposures in the workplace and community.** Occup Environ Med [Internet]. 2003 Jul [cited 2019 Apr 4];60(7):531-8. Available from: http://dx.doi.org/10.1136/oem.60.7.531

16. **Awodele O, Popoola TD, Ogbudu BS, Akinyede A, Coker HA, Akintonwa A. Occupational hazards and safety measures amongst the paint factory workers in Lagos, Nigeria.** Saf Health Work [Internet]. 2014 Jun [cited 2019 Apr 4];5(2):106-11. Available from: https://doi.org/10.1016/j.shaw.2014.02.001

17. **Grosch JW, Neale AV, Demers RY. Neurobehavioral and health-related deficits in solvent-exposed painters.** Am J Ind Med. 1996 Nov;30(5):623-32.

18. **Meyer-Baron M, Blaszkewicz M, Henke H, Knapp G, Muttray A, Schaper M, van Thriel C. The impact of solvent mixtures on neurobehavioral performance: conclusions from epidemiological data.** Neurotox [Internet]. 2008 May [cited 2019 Apr 4];29(3):349-60. Available from: https://doi.org/10.1016/j.neuro.2008.02.005

19. **Ile-Ife** [Internet]. Osun State, Nigeria: The Office of The Executive Governor of the State of Osun; c2019 [cited 2019 Jan 5]. [about 1 screen]. Available from: www.osun.gov.ng/about/major-towns/ile-ife/

20. **Ojo TO, Onayade AA, Akinyemi PA, Adesanmi AJ. Environmental working conditions, lung function and total serum bile acids of spray painters exposed to organic solvents in Ile-Ife, Nigeria.** J Health Pollut [Internet]. 2017 Mar 29 [cited 2019 Apr 4];7(13):2-10. Available from: https://doi.org/10.5696/2156-9614-7-13.2

21. **Neurobehavioural symptom inventory form** [Internet]. Falls Church, VA: Military Health System; 2015 May 1 [cited 2019 Apr 4]. 1 p. Available from: https://health.mil/Military-Health-Topics/Conditions-and-Treatments/Physical-Disability/Traumatic-Brain-Injury?type=Forms+%26+Templates

22. **Kappus MR, Bajaj JS. Assessment of minimal hepatic encephalopathy (with emphasis on computerized psychometric tests).** Clin Liver Dis [Internet]. 2012 Feb [cited 2019 Apr 4];16(1):43-55. Available from: https://doi.org/10.1016/j.cld.2011.12.002 Subscription required to view.

23. **Fidler AT, Baker E, Letz R. Estimation of long term exposure to mixed solvents from questionnaire data: a tool for epidemiological investigations.** Br J Ind Med [Internet]. 1987 [cited 2019 Apr 4];44(2):133-41. Available from: https://oem.bmj.com/content/oemed/44/2/133.full.pdf

24. **Katz DL, Elmore JG, Wild D, Lucan SC. Jekel's Epidemiology, Biostatistics, Preventive Medicine, and Public Health.** 4th ed. Philadelphia, PA: Elsevier Saunders; 2014. 420 p.

25. **Fenga C, Gangemi S, Alibrandi A, Costa C, Micali E. Relationship between lead exposure and mild cognitive impairment.** J Prev Med Hyg. 2016 Dec;57(4):E205-10.