SHORT REPORT

Is colour vision impairment associated with cognitive impairment in solvent exposed workers?

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Occup Environ Med 2004;**61**:76–78

Aims: To determine whether acquired colour vision deficits in solvent exposed individuals are associated with cognitive impairment.

Methods: A sample of 82 painters and 38 other subjects were studied. Alcohol, drug, and smoking histories were obtained. Colour vision was tested using the Lanthony D-15-d colour vision test. Cognitive impairment was measured using the Benton visual retention test, Trail making A, and Trail making B tests. Pre-morbid IQ was estimated using the National Adult Reading Test. Solvent exposure in all subjects was estimated using a previously validated, structured subjective assessment methodology.

Results: After exclusion of subjects with competing causes of colour vision impairment the final group of men numbered 78. There was a significant association on multiple linear regression between the mean colour confusion index (CCI) and three measures of cognitive impairment, the Benton visual retention test, Trail making A, and Trail making B tests after adjusting for the effects of age (or IQ as appropriate), alcohol, and smoking.

Conclusion: Acquired colour vision loss is associated with cognitive impairment in solvent exposed workers. However, given the prevalence of acquired colour vision losses in the adult population, colour vision testing is unlikely to be of value as a screening test.

Acquired colour vision defects in association with exposure to organic solvents have been described in a number of occupational settings over the past 20 years. They tend to be subclinical, affecting principally blue-yellow vision, but may progress to involve red-green vision. Such defects have been associated with exposure to a variety of organic solvents, sometimes at low concentrations. Much of this research has focused on the effects of styrene, but solvent mixtures have also been associated with colour vision deficits. Whether these subclinical signs are markers for more widespread neuropsychological deficits is not clear from the literature.

We have investigated whether subclinical colour vision deficits are associated with cognitive impairment in a sample of painters, the majority of whom had formerly worked in a dockyard, and men sampled from the local community. The subjects represented a range of exposures to solvents, from very heavy and prolonged to (in six individuals) none, but many of the painters had heavy past exposure. We have previously shown that impaired colour vision among these men was associated with increasing intensity of solvent exposure.[1] Similarly we have shown evidence of a negative association between intensity of solvent exposure and performance on a range of cognitive tests.[2] These tests included those measuring visual memory, verbal memory, and planning.

The purpose of the present analysis was to investigate any association between altered colour vision and cognitive impairment in these individuals, in order to see whether colour vision deficits might be proposed as a simple screening test for cognitive impairment.

METHODS

The subjects were selected from those who had taken part in a cross sectional study of survivors of a cohort of dockyard painters and community controls.[3] All were volunteers who were prepared to agree to extensive neuropsychological testing and to provide a detailed lifetime occupational history. One hundred and twenty subjects took part in the study (38 non-painters and 82 painters). The study was approved by the joint research ethics committee of Aberdeen University and Grampian Health Board and all participants gave written informed consent.

We have previously described the methods employed for colour vision testing in the subjects.[1] Briefly, they were asked about history of diabetes or congenital colour vision deficits. Alcohol, drug, and smoking histories were obtained from all subjects. Their visual acuity was measured using a half-size Snellen chart, and colour vision was tested, in each eye separately, using the Lanthony D-15-d test, a test especially sensitive to acquired colour vision losses.[4] Exclusion criteria for the colour vision element of the study included low visual acuity (>6/30) in either eye, congenital colour vision deficit, diabetes, or solvent exposure within the previous 16 hours. The results of colour vision testing were analysed, using the methodology of Bowman to generate a mean colour confusion index (CCI).[5]

The cognitive tests included the Benton visual retention test (form C, administration A), and Trail making A and B tests. The Benton visual retention test assesses visuomotor response, visuospatial perception, visual and verbal conceptualisation, and immediate memory span. It generates two outcome measures: the number of correct reproductions (out of 10) and the number of errors made, where more than one error can be made in each incorrect reproduction. The Trail making tests are tests of visuomotor tracking and visual conceptualisation. These tests are measured in terms of time to completion (seconds) where an increasing time equates to a poorer performance. Premorbid IQ was estimated using a hold test, the national adult reading test (NART).

We obtained detailed work histories from all subjects. These interviews, together with data from dockyard solvent monitoring, paint manufacturers' data, exposure reconstructions, and painters' job diaries, had been used within a previously validated exposure assessment methodology to produce estimates of cumulative solvent exposure (CE) expressed as working years at a concentration equivalent to the occupational exposure level (OEL-years).[6]

Main messages

- Acquired colour vision impairment in solvent exposed workers is associated with cognitive impairment.
- Solvent exposures have been associated with acquired colour vision losses.
- The Lanthony D-15-d cannot be recommended as a screening test for cognitive impairment as there are many other causes of acquired colour vision loss.

Policy implications

- Health effects are detectable in workers below current UK exposure standards for mixed solvent exposures.
- Acquired colour vision losses are associated with other health effects and should not be dismissed as subclinical effects of only academic interest.

Statistical analysis was carried out using SPSS v. 9.0. The relations between Benton score, Benton error score, Trail making A, and Trail making B, and CCI were investigated using multiple regression, adjusting for smoking and alcohol consumption in all subjects. Smoking was treated as a categorical variable, taking a value of 0 for non-smokers and a value of 1 for smokers. We adjusted also for IQ in the case of the Benton score and Benton error score and for age for Trail making A and B. The Benton visual retention test error score, and the results of Trail making A and B were log transformed using natural logarithms prior to analysis.

RESULTS

The mean CCI for all 82 painters was 1.5 (range 1–4.5, SD 0.54) and for the 38 non-painters was 1.4 (range 1–3.2, SD 0.46). After excluding individuals with low visual acuity, congenital colour vision deficits, or a competing cause for acquired colour vision losses, the final group for analysis was reduced to 78 individuals (50 painters and 28 non-painters). Figure 1 shows the range of cumulative exposures to solvents of the individuals in the study.

The mean estimated IQ (NART) for the final group of 82 was 102.4 (range 77–123, SD 9.99). The mean age of the final group was 53.3 years (range 29–79, SD 10.9) and the mean alcohol consumption was 12.6 units/week (range 0–65, SD 12.25). There were 26 smokers in the final group. Univariate analyses were undertaken to screen for correlation between the psychometric test variables and IQ, age, and alcohol. With the exception of alcohol all independent variables were significantly correlated with the dependent variables. Alcohol was included in the regression analyses as previous research has shown an effect on cognitive function.[7] Smoking was not included in the correlations as it is a dichotomous variable, but was included in the regression analyses as it has previously been shown to have an effect on cognitive function.[8]

After adjustment for the effects of IQ, alcohol, and smoking, the CCI was significantly associated with both the Benton visual retention test score ($p = 0.002$) and the Benton visual retention test error score ($p = 0.001$) (table 1). For the Benton score (no log transformation) each unit increase in CCI was associated with a 1.97-fold decrease in Benton score, when all other independent variables (IQ, smoking, and alcohol here) were held constant. For the Benton error score (logged) each unit increase in CCI was associated with a 2.25-fold increase in Benton error score, when all other independent variables were held constant. After adjustment for the effects of age, alcohol, and smoking, there was a significant association with performance on both Trail making A ($p = 0.010$) and B tests ($p = 0.023$) (table 1). Each unit increase in CCI was associated with a 1.50 and 1.47-fold increase in Trail making A and Trail making B respectively.

DISCUSSION

Several groups, including our own, have shown an association between solvent exposure in the workplace and acquired colour vision losses. This evidence of neurotoxicity suggests that colour vision testing might be useful as a marker of other neuropsychological deficits in exposed workers. A Californian

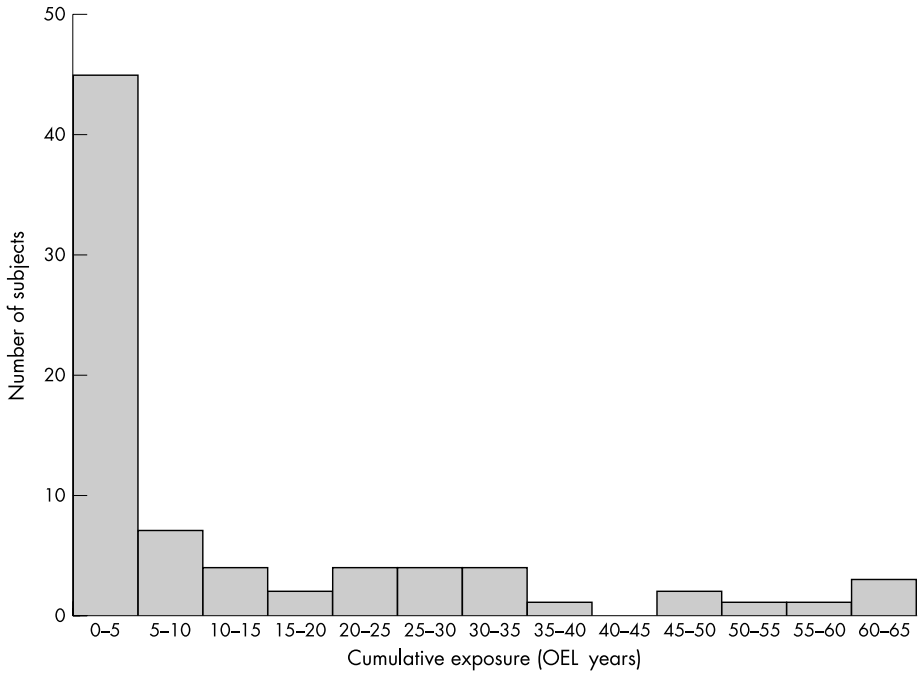

Figure 1 Cumulative solvent exposures for all subjects (n = 78).

Table 1 Relations between psychometric tests and colour vision

Dependent variable	Independent variables	Regression coefficient	95% CI	p value
Benton score	CCI	−1.97	−3.21 to 0.72	0.002
	IQ	0.05	0.02 to 0.08	0.002
	Smoking	−0.40	−1.08 to 0.08	0.249
	Alcohol	0.01	−0.02 to 0.03	0.673
	Constant	4.46	0.51 to 8.41	0.027
Benton error score*	CCI†	0.81	0.33 to 1.29	0.001
	IQ	−0.02	−0.04 to 0.01	<0.001
	Smoking	0.12	−0.14 to 0.39	0.359
	Alcohol	−0.004	−0.01 to 0.01	0.429
	Constant	2.80	1.26 to 4.33	0.001
Trail A* (seconds)	CCI‡	0.41	0.10 to 0.72	0.010
	Age	0.01	0.01 to 0.02	0.001
	Smoking	−0.01	−0.17 to 0.15	0.913
	Alcohol	0.003	−0.003 to 0.01	0.357
	Constant	2.30	1.84 to 2.75	<0.001
Trail B* (seconds)	CCI§	0.39	0.06 to 0.72	0.023
	Age	0.02	0.01 to 0.03	<0.001
	Smoking	0.09	−0.08 to 0.26	0.295
	Alcohol	0.003	−0.004 to 0.01	0.423
	Constant	2.78	2.29 to 3.28	<0.001

CI, confidence interval.
*Benton visual retention test error score, Trail making A, and Trailing making B were log transformed before analysis.
†Taking antilogs, regression coefficient is 2.25, 95% CI 1.39 to 3.63.
‡Taking antilogs, regression coefficient is 1.50, 95% CI 1.11 to 2.05.
§Taking antilogs, regression coefficient is 1.47, 95% CI 1.06 to 2.05.

study of disabled workers with neuropsychological impairment found that 17 of the 21 subjects had impaired colour vision.[9] This study found that colour vision loss was linked to poor performance in those psychometric tests heavily dependent on the visual pathways. Little information is given in the report on the exposure histories of the subjects, some of whom had been exposed to pesticides and freon.

We found that 78 of the 120 participants in our study met the criteria for inclusion in the colour vision analysis. The remaining 42 subjects were excluded because of coexisting disease, low visual acuity, recent solvent exposure (within the previous 16 hours), or another competing cause for acquired colour vision loss. Our results were consistent with a relation between CCI and impaired performance on the Benton visual retention test and Trail making tests. However, almost any disease that affects visual acuity will have an impact on colour perception; the prevalence of acquired dyschromatopsia in the community is about 8%, as illustrated by our exclusion rate. This leads us to believe that, in spite of the association, use of the CCI would be inappropriate as a surrogate for psychometric testing or exposure assessment in solvent exposed groups.

ACKNOWLEDGEMENTS

We thank the British Occupational Health Research Foundation, the Health and Safety Executive, and Grampian University Hospitals Research Endowment Trust for support for this study. FD was the recipient of a travelling scholarship from the William Ramsay Henderson Trust. We gratefully acknowledge the support of these bodies.

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Accepted 24 February 2003

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