VISUAL ASSESSMENT BY PSYCHOPHYSICAL METHODS OF PEOPLE SUBJECTED TO OCCUPATIONAL EXPOSURE TO ORGANIC SOLVENTS[1]

Eliza Maria da Costa Brito Lacerda
Dora Fix Ventura
Luiz Carlos de Lima Silveira

Abstract: Organic solvents are neurotoxic substances that can cause damaging effects in the visual system. Occupational exposure to these substances is common because they are used in a wide variety of activities. These effects can be quantified by specific psychophysical tests. The most commonly used tests for color vision assessment are arrangement tests, such as the Lanthony Panel D-15 desaturated test and the Farnsworth-Munsell 100-hue test, and for contrast sensitivity assessment, printed panel tests such as the MCT 8000 VISTECH, VCTS 6500VISTECH, and FACT 101 tests. Generally, these tests show color discrimination losses in the blue-yellow and red-green axis, and a decrease in contrast sensitivity, mainly at low spatial frequencies. There is a positive correlation between psychophysical results and biological environmental markers, but this correlation depends on the marker and on the kind of solvent

1 Financial support: CNPq-PRONEX / FAPESPA #2268 e #089/2010; CNPq #486351/2006-8, #620037/2008-3 e #476744/2009-1; CAPES-PROCAD #182/2007; FINEP IBN-Net (Brazilian Neuroscience Institute Net). E-mail: eliza_lacerda@yahoo.com.br

to which the individuals are exposed. Factors such as alcohol and tobacco can interfere with the correlation of the results.

Keywords: Organic solvents. Occupacional exposure. Visual psichophisics. Color vision. Contrast sensitivity.

Organic solvents are substances composed of hydrocarbons that are liquid at temperatures from 0 to 250 oC (Occupational Safety and Health Information Series [OSHS], 1998) to which millions of people worldwide are exposed due to its widespread use in industry, agriculture, university and houses. The wide applicability of these substances makes this exposure may be due to several factors, foremost among them the occupational factor because this is the most aggressive to human health. The great demand of organic solvents chronically exposed workers has made this an important point of discussion in occupational medicine and thus led to increasingly detailed studies on the subject (Hanninen et al., 1976, Mergler et al., 1990; Ahmadi et al. 2002; Boeckelmann & Pfister, 2003, Semple et al., 2007). Most occupational exposure to organic solvents occurs for mixtures of solvents, and inhalation route is the main pathway of contact for the organism (Hanninen et al. 1976; Mikkelsen, 1980, Olsen et al., 1980, Pfister et al. 1999; NOHSC, 1990; Boeckelmann & Pfister, 2003).

Organic solvents are substances with neurotoxical properties that can affect both the central nervous system and peripheral nervous system. The assaults on the nervous system are caused probably due to the lipophilic properties of organic solvents (Rosenberg, 1989). Generally the attacks occur in the lipid structures of nerve tissue, specifically the myelin sheath of axons and the cellular membrane (Boeckelmann & Pfister, 2003). Several symptoms resulting from occupational exposure have been reported, including anxiety, irritability, fatigue, depression, loss of concentration, memory loss, loss of motivation, cognitive loss, dementia, postural change in regulation, myalgia, numbness of limbs and loss of vision (Baelum et al. 1982; Lee & Lee, 1883; Gregersen et al., 1984, Linz et al. 1986; Gregersen et al., 1987, Morrow et al. 1989; Rosenberg, 1989; NOHSC, 1990; Baker, 1994, Dick et al. 2002; Viaene et al. 2009; Herpin et al., 2009). It has also been reported that organic solvents have genotoxic properties (Lemanster et al., 1997) and epidemiological studies have shown that exposure to organic solvents is a risk factor for neurological diseases such as Parkinson's disease (Smargiassi et al., 1990), multiple sclerosis (Amaducci et al. 1982; Flodin et al., 1985) and myasthenia gravis (Rosenberg, 1989,

Gunnarsson et al. 1992; Chancellor et al. 1993; Schulte et al. 1996; Graham et al., 1997).

The visual function has been used as an important indicator neurointoxication by organic solvents (Baelum et al., 1982, Horan et al. 1985). An abnormal vision may be related to the presence and may be the earliest symptom of optic neuropathies (Rosen, 1965), encephalopathy (Paalysaho et al., 2007), cognitive impairment (Dick et al., 2004) and other neurotoxical effects (Mutray et al., 1995, Ihrig et al., 2003).

Organic solvents are responsible for changes in different parts of the visual system. Among the tests used for visual assessment of subjects exposed to occupational mixture of organic solvents, the psychophysical tests stand out for their efficiency in detecting changes, revealing losses before the onset of clinical phenomena evident, and the possibility of analysis of different functions visual separately (Lacerda et al., 2009).

This paper presents a brief review of the psychophysical tests that have been described in literature as the most suitable for assessing color vision and contrast sensitivity of subjects due to occupational exposure to organic solvents.

Psychophysical assessment of color vision of subjects due to occupational exposure to organic solvents

D15 desaturated test of Lanthony (D15D)

The D15 desaturated test of Lanthony (D15D) is based on the ability of the subject order 15 pieces of desaturated hues approximately equidistant from each other along a boundary provisions of color space whose center is an achromatic region (Figure 1), each eye is tested separately and the results are quantitatively evaluated by color confusion index (CCI) (Bowman, 1982). The ICC has a value when all the pieces are properly positioned and increases as the number of errors the subject. It can be calculated by the following formula:

$$ICC = \frac{\text{valor de erro do examinando}}{\text{valor de erro de referência}}$$

With the use of desaturated test Lanthony D15d or loss of color vision can be classified into losses to the axis red-green confusion, losses to the axis of blue-yellow confusion and diffuse losses (Verriest, 1963, Geller & Hudnell, 1997). This method is similar to Test Farnsworth D-15, a

shorter version of only 15 pieces of test 100-Munsell Hues of Farnswoth (Farnsworth, 1943). However, D15d the hues of the pieces are more desaturated, which allows the detection and quantification of dichromatic subjects more accurately than in the Farnsworth D-15 – a test used to screen for congenital defects (Birch, 2001).

The D15d is the most sensitive test described in the literature for assessment of color vision in subjects exposed to organic solvents and this is due to the fact of enabling the detection of subclinical loss of color vision, be especially sensitive to visual impairments of blue-yellow vision and, moreover, have the great advantage for portability and quick application of the methodology. It is a test for the detection of loss of color vision acquired in workers exposed to organic solvents (Mergler & Blain, 1987).

To D15d studies using the assessment of subjects due to occupational exposure to organic solvents have revealed loss of color vision. For example, the study by Mergler and Blain (1987) studied the color vision of workers exposed to mixtures of organic solvents such as acetone, methyl ethyl ketone, toluene, xylene, styrene, 2-etanoxi-ethanol, ethanol-2-etanoxi acetate. These authors observed a prevalence of 52.2% loss of color vision in subjects with moderate or high exposure. These losses occurred for blue-yellow vision, and in some cases, also for red-green vision.

Similar results were obtained in workers chronically exposed to mixed solvents containing ketone, methyl ethyl ketone, 1, 2-dichloroethane, butyl acrylate, methyl isobutyl ketone, toluene, n-butanal, acetone, ethyl-benzene, xylene, styrene and cyclohexanone (Gong et al., 2003), and residents of apartments with laundry and laundry employees exposed to tetrachloroethylene (also known as tetrachloroethene or perc) (Schreiber et al., 2002).

In the assessment of factory workers exposed to other petrochemical distillation solvent mixture containing isopentane, hexane, heptane, octane, cyclohexane, methyl cyclohexane, benzene, toluene, xylene, ethyl benzene, 1,1,1-trichloroethane and methyl tertiary-butyl ether, has been described loss of color vision age-dependent and independent axis of confusion a specific color (Lee et al., 2007). Color vision deficiency dependent on exposure time and age was also commonly observed in painters exposed to a solvent mixture which included xylene, methyl ethyl ketone, naphtha, 2-ethoxy ethanol, acetone and dichloromethane (Semple et al., 2000), in painters exposed to toluene and styrene-exposed workers, who had vision loss to both blue-and green-red Marel (Eguchi et al., 1995, Campagna et al., 2001). In the study by Mergler and colleagues (1988) workers chronically exposed to mixtures of organic solvents had diffuse color vision loss, but no correlation with age.

The association of color vision deficiency with evidence of chronic encephalopathy in subjects exposed to organic solvents suggests that an altered color vision for these subjects is an important risk factor for neuropsychological disorders (Semple et al., 2000), including the cognitive loss (Dick et al., 2002).

However, not all color vision deficiency in occupational exposure detected by D15d is directly related to cognitive impairment. This was observed in the study of painters with color vision deficiency that when underwent cognitive testing showed no correlation between the degree of visual loss and the degree of cognitive impairment (Ihrig et al., 2003, Dick et al., 2004)However, not all color vision deficiency in occupational exposure detected by D15d is directly related to cognitive impairment. This was observed in the study of painters with color vision deficiency that when underwent cognitive testing showed no correlation between the degree of visual loss and the degree of cognitive impairment (Ihrig et al., 2003, Dick et al., 2004).

The D15d has been recommended for assessment of color vision of subjects exposed to organic solvents (Mergler & Blain, 1987) and shows some association between loss of color vision and cognitive impairment (Dick et al., 2002). However, it can not be used directly as a screening test for cognitive impairment. In some studies, loss of color vision detected by D15d restricted to a particular age group of subjects studied, as was the case with painters in the study which revealed that subjects aged between 25 and 55 years showed a significant decrease of vision color as subjects above 55 years had no visual change (Ihrig et al., 2003).

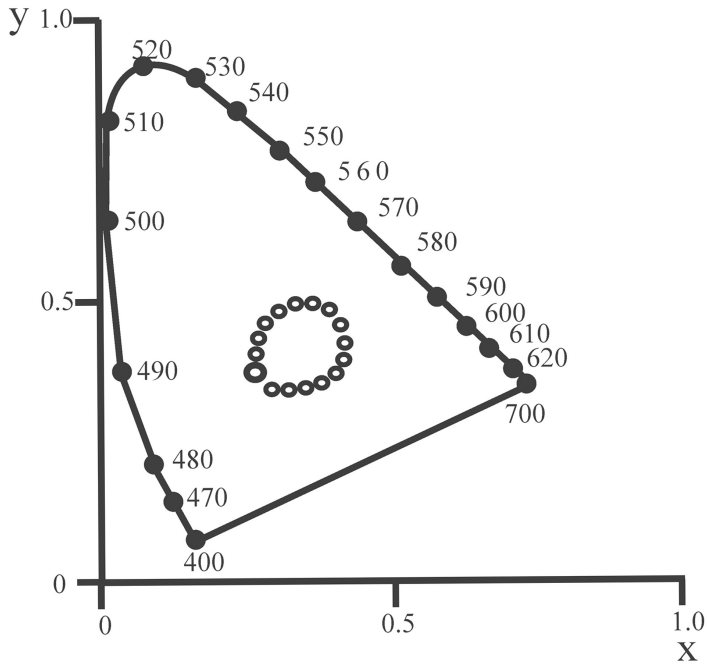

Figure 1. Localization of D15d caps in the CIE1931 color space. Circles indicated each cap starting from the reference cap (larger circle).

Farnsworth-Munsell 100 Hue Color Vision Test (FM-100)

FM-100 is based on the ability of the subject to order 85 pieces painted with shades of the same saturation and brightness and photopic lighting in a sequence of chromatic color space.

Each eye is tested separately and the results are quantitatively evaluated according to the error value of the subject (Farnsworth, 1957). Each hue has a number of planning, unknown by the subject tested. The magnitude of the error is calculated for each piece. It is proportional to the distance between the position made by the subject and the correct position of the piece.

The FM-100 is less sensitive than the D15d and can serve to detect false positives obtained by D15d (Hudnell & Geller, 1997; Iregren, 2002). Workers exposed to mixtures of organic solvents, including acetone, methyl ethyl ketone, toluene, xylene, styrene, etanoxi-2-2-ethanol and ethanol-acetate-etanoxi assessed by the FM-100, had a prevalence of 47.2% loss of color vision in subjects with moderate and high exposure. These losses occurred for the blue-yellow vision, and in some cases, also for red-green vision. These results were compared in the same job with the results of D15d for which the prevalence was higher (52.25%) and, as

mentioned above, the FM-100 was important for the detection of false positives obtained by D15d (Mergler & Blain, 1987).

Color vision defects associated polyneuropathy has also been described for occupational exposure to n-hexane, in which the error values in part (blue-yellow or red-green) and total (blue-yellow over red-green) were significantly higher in exposed subjects compared with control subjects (Issever et al., 2002).

Subjects exposed to organic solvents had higher mean values of error in the FM-100 than subject of the control group and the damage of color vision is associated with the presence of chronic encephalopathy or may be caused by chronic encephalopathy induced by exposure to solvents, so the use of FM-100 can generate indicators for the stage of encephalopathy (Paallysaho et al., 2007). Occupational exposure to styrene does not result in error values in the FM-100 subjects exhibited significantly higher compared with control subjects, although subjects tended to be more exposed to the axis error of confusing colors suggesting that exposure to moderate concentrations of styrene can cause loss of color vision (Fallas et al., 1992).

In the Laboratory of Neurophysiology "Eduardo Oswaldo-Cruz" and the Laboratory of Tropical Neurology, both at UFPA, a computerized version of the 100 Test Farnsworth-Munsell Hues (Figure 2) (Braga, 1996; Rodrigues, 2003, Silveira et al. 2003, Rodrigues et al., 2007) was used in the evaluation of the attendants of fuel distributor and found results similar to those described in the literature to the printed version of this test, showing color vision loss in the diffuse type (Lacerda et al. 2008, 2010, Lacerda, 2010) (Figure 3).

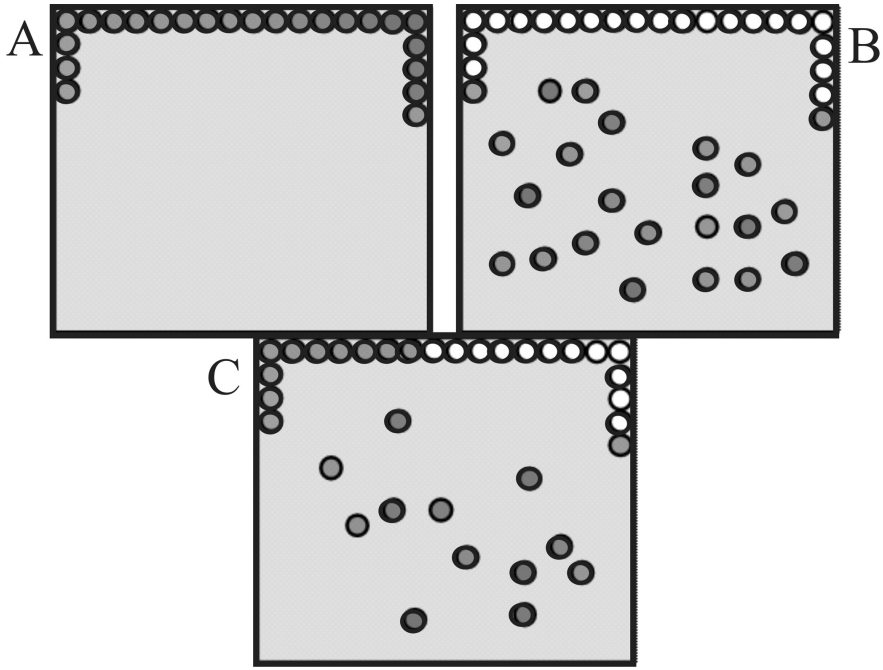

Figure 2. Scheme of FM-100 hue test. (A) Original ordering of the caps showing a gradual change in the hue information. (B) The test starts when the caps are mixed. (C) The subject's task is to reorder the caps in the same sequence of hue viewed in (A).

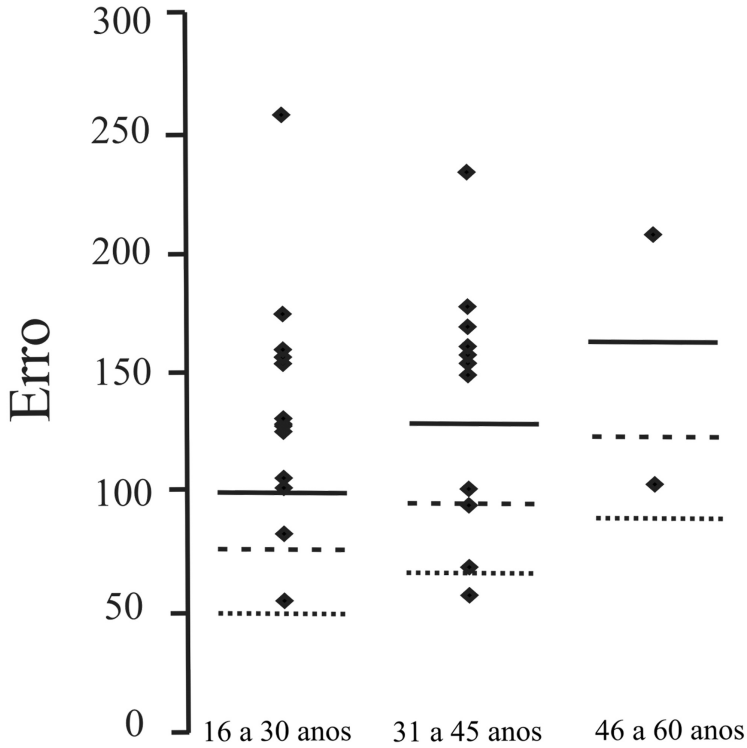

Figure 3. Results from color vision evaluation using FM-100 test of solvent exposed workers in three different age-ranges. Continuous lines represent the upper tolerance limit of control group. Dashed lines represent the standard deviation of control group. Pointed lines represent mean error values of the control group. Black symbols represent the error values of the solvent exposed group.

Table 1 summarized the studies discussed above.

Table 1. Psychophysical studies of color vision of organic solvent chronically exposed workers.

Estudo	Tipo de Solvente	Teste	Conclusão
Mergler & Blain, 1987	Acetona, metil-etil-cetona, tolueno, xileno, estireno, 2-etanoxi- etanol, 2-etanoxi-etanol-acetato	D15D, FM-100	Perda de visão de cores azul-amarelo e, em alguns casos, verde-vermelho em sujeitos com exposição moderada e alta. Teste D15D tem maior prevalência de alteração que o FM-100
Gong *et al.,2003*	Cetona, metil-etil-cetona, 1,2-dicloroetano, butil-acrilato, metil-isobutil-cetona, tolueno, n-butanal-acetona, etil-benzeno, xileno, estireno e cicloexanona	D15D	Perda de visão de cores
Schreiber *et al.*, 2002	Tetracloroetileno	D15D	Perda de visão de cores
Lee *et al.*, 2007	Isopentano, hexano, heptano, octano, cicloexano, metil-ciclohexano, benzeno, tolueno, xileno, etil-benzeno, 1,1,1-tricloroetano e metil-terciário-butil-éter	D15D	Perda de visão de cores dependente da idade e independente de um eixo de confusão de cores específico
Semple *et al.,* 2000	Xileno, metil-etil-cetona, nafta, 2,etoxi-etanol, diclorometano e acetona	D15D	Deficiência na visão de cores dependente da idade
Eguchi *et al.*, 1995	Estireno	D15D	Perda de visão de cores azul-amarela e verde-vermelha
Campagna *et al.,* 2001	Tolueno	D15D	Perda de visão de cores azul-amarela e verde-vermelha

Mergler *et al.*,1988	Misturas de solventes	D15D	Perda de visão de cores azul-amarela e verde-vermelha, sem correlação com idade
Semple *et al.,* 2000	Misturas de solventes	D15D	Alteração de visão de cores é um importante fator de risco para alterações neuropsicológicas
Dick *et al.*, 2002	Misturas de solventes	D15D	Alteração de visão de cores é um importante fator de risco para perda cognitiva
Ihrig *et al.*, 2003	Misturas de solventes	D15D	Grau de perda de visão de cores sem correlação com grau de perda cognitiva
Dick *et al.,* 2004	Misturas de solventes	D15D	Grau de perda de visão de cores sem correlação com grau de perda cognitiva
Ihrig *et al.*, 2003	Misturas de solventes	D15D	Perda de visão de cores restrita à faixa etária de 25 a 55 anos
Issever *et al.*, 2002	N-hexano	FM-100	Deficiência na visão de cores associada à polineuropatia
Paallysaho *et al.*, 2007	Mistura de solventes	FM-100	Dano na visão de cores associada à presença de encefalopatia crônica
Fallas *et al.,* 1992	Estireno	FM-100	Sem número de erros significativamente maior que controles, mas com tendência de erros maiores nos eixos de confusão de cores
Lacerda *et al.*, 2008, 2010; Lacerda, 2010	Mistura de solventes	FM-100 computadorizado	Perda na visão de cores do tipo difusa

Psychophysical assessment of spatial luminance contrast vision of subjects due to occupational exposure to organic solvents

Multivision Contrast Test Vistech MCT 8000

Test Multivision Contrast Vistech MCT 8000 (Vistech Consultants, Dayton, Ohio) is a test chart printed using controlled techniques and advanced photographic and printing devices in order to minimize loss of the quality of the printed image and maximize the accuracy of measurements of spatial frequency, orientation and contrast of visual stimuli used in testing. The MCT 8000 Vistech is used to evaluate the vision of luminance contrast in five spatial frequencies, 1.5, 3, 6, 12 and 18 cycles per degree of visual angle or cpd. The pack contains visual stimuli distributed in five rows and seven columns. Each of the five lines is filled by seven circles showing sinusoidal gratings, in which the luminance varies along one dimension, and is constant in the dimension perpendicular to this. The luminance contrast decreases on each line of the first into the seventh element, while the spatial frequency increases from one line to the next, from top to bottom. Along each line stimuli also vary randomly oriented and can be oriented vertically, tilted to the right or left-leaning.

In this test, the subject whose vision is being evaluated is instructed to respond in what direction the network is being presented – tilted to the right, leaning left or vertically. Proceeding from left to right on each row of stimuli, the subject is asked to identify the orientation of the sinusoidal grating presented in each stimulus, the contrast of the last correctly identified stimulus is thus considered as the contrast threshold for spatial frequency line corresponds to the stimuli presented. It is necessary, then from row to row, checking the contrast threshold for the set of spatial frequencies that comprise the test. The result is a set of five points on the chart contrast sensitivity (inverse of contrast threshold) as a function of spatial frequency which is about the role of spatial contrast sensitivity to luminance of the subject tested.

This assessment test of spatial luminance contrast vision was used by Gong et al. (2003) in subjects chronically exposed to a mixture of solvents containing ketone, methyl ethyl ketone, 1,2 dichloroethane, butyl acrylate, methyl isobutyl ketone, toluene, n-butanal, acetone, ethyl benzene, xylene, styrene and cyclohexanone. In this work they found that in all spatial frequencies contrast sensitivity assessed spatial luminance was lower in exposed subjects compared with the control group subjects, there was statistical difference in spatial frequencies of 6 and 12 cpd.

Vision Test System Contrast VCTS Vistech 6500

The Vision Test System Contrast VCTS 6500 (Vistech Consultants) consists of a panel of stimuli similar to the MCT 8000, measuring 68.6 x 94.0 cm and consisted of five rows and nine columns with 45 rounds of 74 stimuli occupying mm in diameter, separated by 3 mm distance, networks containing sinusoidal vertical, inclined to the left of the 15th or 15th to the right, presented the subject to be tested with average luminance of 100 cd/m2. The contrast of the stimulus decreases horizontally from left to right, columns corresponding to columns numbered from 1 to 9, and the spatial frequency increases from top to bottom, lines corresponding to the letters A to E, corresponding to spatial frequencies of 1.5, 3, 6, 12 and 18 cpd in viewing distance recommended by the manufacturer of 3 m.

The subject is instructed to view the stimuli sequentially, row by row (from top to bottom) from left to right, identifying the orientation of the grating and responding vertical, tilted left, tilted to the right or not see the grating. The contrast of the last stimulus of each line orientation whose grating had correctly identified by the subject corresponds to the contrast threshold in the spatial frequency corresponding to the line and contrast sensitivity, as already mentioned, is the inverse of contrast threshold. Lighting conditions recommended by the manufacturer, 30-60 ftL if the subject is able to see the grating presented lower contrast, their contrast sensitivity is between 100-300 at the four lowest spatial frequencies presented and slightly below 100 for the highest spatial frequency tested.

Boeckelmann and Pfister (2003) used this test in the study of contrast sensitivity of painters exposed to organic solvent mixtures containing acetone, 2-butoxietil-acetate, n-butyl acetate, 2-ethoxyethanol, ethyl acetate, ethyl-benzene, isopropyl-benzene, 1-methoxy-2-propanol, ethyl acetate, ethyl benzene, isopropyl benzene, 1-methoxy-2propanol, toluene and xylene. The painters had significantly lower contrast sensitivity than the control at all spatial frequencies. The loss in contrast sensitivity was associated with visual acuity significantly affected.

Functional Acuity Contrast Test – F.A.C.T 101

The Functional Acuity Contrast Test (F.A.C.T. 101) is a test of spatial contrast sensitivity to luminance measured by the ability to distinguish subtle differences in grayscale (sensitivity to luminance contrast is a measure of the ability to distinguish differences in grayscale appear side by side or sequentially – contrast sensitivity and temporal, respectively). The stimuli used in this test and how the test is conducted, is similar to that described previously for the VCTS Vistech 6500.

This procedure for evaluating the sensitivity to luminance contrast was used by Schreiber et al. (2002) who studied residents of apartments with laundry and laundry employees exposed to tetrachloroethylene, also known as tetrachloroethene, or perc. These individuals were exposed, both residents and workers, had reduced contrast sensitivity in the control group for all spatial frequencies. These losses, as in the study by Boeckelmann and Pfister (2003), are accompanied by visual impairment.

Determination of the spatial contrast sensitivity to luminance by computerized test

In the Laboratory of Neurophysiology "Eduardo Oswaldo-Cruz" (Institute of Biological Sciences) and Laboratory of Tropical Neurology (Tropical Medicine Nucleus), UFPA, a computerized test designed to assess the spatial contrast sensitivity to luminance to 11 spatial frequencies (Botelho de Souza, 1995, Silveira et al., 2003, Rodrigues et al., 2007).

The test consists of a program written in C + +, which generates a screen cathode ray stimuli composed of stationary isochromatic gratings (CIE 1976, white: u = 0.182, v'= 0474) whose luminance varies sinusoidally in the horizontal direction. Mean luminance of the stimulus is 43.5 cd/m2, regardless of changes in spatial frequency and contrast. Eleven spatial frequencies are used: 0.2, 0.5, 0.8, 1, 2, 4, 6, 10, 15, 20 and 30 cpd. The pattern is displayed in a rectangular window measuring 6.5° by 5° of visual angle at a distance of 3 m when it is presented (Figure 4) (Rodrigues, 2003).

With this test, were evaluated attendants of fuel distributors chronically exposed to organic solvent mixture and they found a decrement in contrast sensitivity at least one spatial frequency at 52% of the sample. There was no concomitant alteration in a consistent visual acuity (Lacerda et al., 2008, 2010, Lacerda, 2010) (Figure 5).

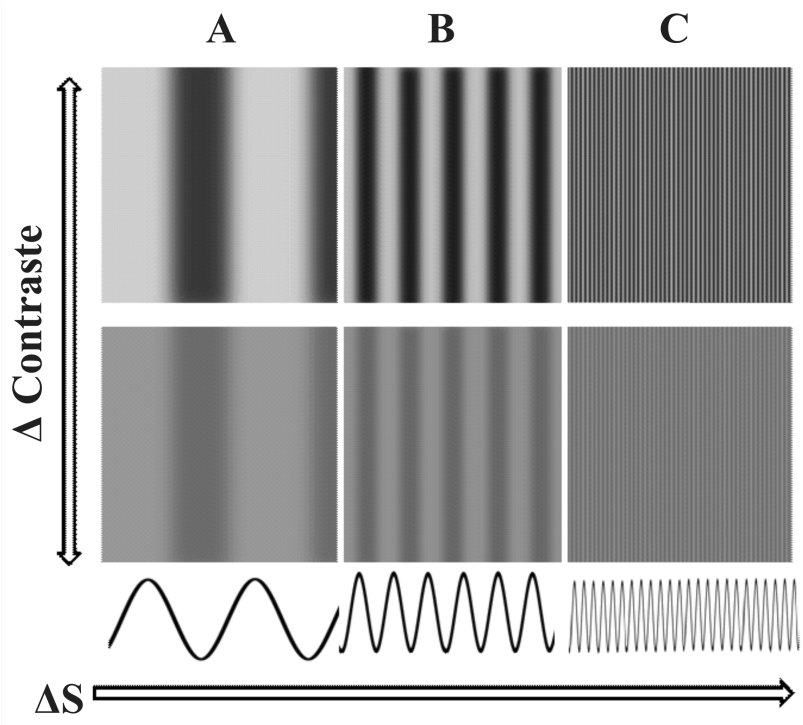

Figure 4. Stimuli used to estimate the spatial contrast sensitivity function. In A, B, and C have stimuli with spatial frequencies from low (A) to high (C) values. Upper stimuli have high contrast, whilst lower stimuli have low contrast.

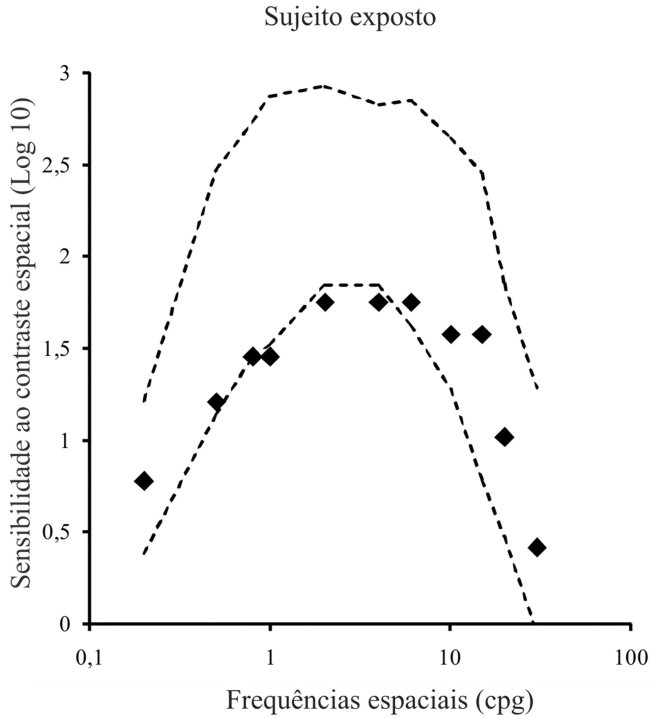

Figure 5. Result of the estimative of contrast sensitivity function from a solvent exposed worker. Dotted lines limit the tolerance interval of a control group. Black symbols are the contrast sensitivity values at different spatial frequencies of exposed subject.

Table 2 summarizes the studies discussed before.

Table 2. Psychophysical studies of luminance contrast of solvent exposed workers.

Estudo	Tipo de Solvente	Teste	Conclusão
Gong *et al.*, 2003	Cetona, metil-etil-cetona, 1,2 dicloroetano, butil-acrilato, metil-isobutil-cetona, tolueno, n-butanal-acetona, etil-benzeno, xileno, estireno e cicloexanona	MCT 8000 Vistech	Diminuição da sensibilidade em todas as frequências espaciais; diferença estatística somente para 6 e 12 cpg.
Boeckelmann & Pfister, 2003	Acetona, 2-butoxietil-acetato, n-butil-acetato, 2-etoxietanol, etil-acetato, etil-benzeno, isopropil-benzeno, 1-metoxi-2-propanol, etil-acetato, etil-benzeno, isopropil-benzeno, 1-metoxi-2propanol, tolueno e xileno	VCTS 6500 Vistech	Perda de sensibilidade ao contraste em todas as frequências espaciais associada à acuidade visual diminuida
Schreiber *et al.*, 2002	Tetracloroetileno	FACT 101	Perda de sensibilidade ao contraste em todas as frequências espaciais associada à acuidade visual diminuida
Lacerda *et al.*, 2008, 2010; Lacerda, 2010	Mistura de solventes	Teste computadorizado desenvolvido na UFPA	Diminuição da sensibilidade ao contraste em pelo menos uma das frequências espaciais, sem alteração da acuidade visual

Correlation between results of visual psychophysical assessment of subjects exposed to occupational solvents and the levels of biomarkers and environmental

Monitoring the effects of exposure to organic solvents on the visual system is very important because being able to use that knowledge to prevent or minimize the damage caused by the interaction of these substances to the body and also to subsidize the creation of environmental standards have a wider application in the health of workers and the general population (Amorim, 2003).

Thus, it is important to correlate levels of different markers and quantitative results obtained by psychophysical methods of visual

assessment, information about dose-exposure time-response for each type of exposure and the degree of intoxication of individuals examined in order that changes in visual perception have been identified as early signs of neurotoxicity (Rosen, 1965; Baelum et al., 1982, Horan et al. 1985, Mutray et al., 1995, Ihrig et al., 2003, Dick et al. 2004; Paalysaho et al., 2007).

One way to quantify exposure to organic solvents is to relate the working time and daily activity of subjects exposed and half-life of substances to which subjects are exposed. Color vision of painters exposed to mixed solvents that were included xylene, methyl ethyl ketone, naphtha, 2-ethoxy ethanol, acetone and dichloromethane, was assessed with the D15d and correlated the results with two methods of measurement of exposure widely used, the index of recent exposure indicating exposure in the last 12 months for each subject tested and chronic exposure index is a measure of cumulative exposure throughout the working time of the individual, observing a positive correlation between the extent of commitment and the degree of visual exposure (Semple et al, 2000).

In a study of color vision of painters exposed only to toluene was used as a marker of environmental organic solvent level in a sample of air from the work environment obtained by chromatography and the biological indexes as markers of cumulative exposure to toluene and total hydrocarbons, which considers the dosage of these substances in the air of work environment during working hours and according to the chemistry employed during this period. These data were compared with results obtained with the D15d and there was a significant correlation between the impairment of color vision and the levels of toluene in the air (environmental marker) and index of cumulative exposure to toluene and total hydrocarbon (biomarkers) (Campagna et al., 2001).

Workers in a petrochemical distillation factory exposed to solvent mixtures containing isopentane, hexane, heptane, octane, cyclohexane, methyl cyclohexane, benzene, toluene, xylene, ethyl benzene, 1,1,1-trichloroethane and methyl tertiary- butyl ether and whose color vision was tested with D15D, it was observed that visual impairment was correlated with exposure levels and working time, and a visual impairment compared versus highest exposure for the left eye (Lee et al., 2007).

Already in painters exposed to organic solvent mixtures containing acetone, 2-butoxietil-acetate, n-butyl acetate, 2-ethoxyethanol, ethyl acetate, ethyl benzene, isopropyl benzene, 1-methoxy-2-propanol, ethyl acetate, ethyl benzene, isopropyl benzene, 1, 2-methoxy, propanol, toluene and xylene was used as a marker of exposure time in years of exposure to organic solvents and this time compared with the spatial contrast

sensitivity to luminance obtained with VCTS Vistech 6500, observing a weak correlation (Boeckelmann & Pfister, 2003). In addition, similar work evaluating painters exposed to mixed organic solvents not specified was not found significant association between these two parameters (Ihrig et al., 2003).

As is noted, however, the concentrations of organic solvents or metabolites in the body exposed are not directly related to exposure time. It is known, for example, the existence of genes that encode enzymes responsible for metabolism of organic solvents and that the polymorphism modifies the absorption and the risk of neurotoxical effects between individuals (Söderkvist et al., 1996). Factors including age and susceptibility differences between individuals in the pattern of absorption of organic solvents are involved in the metabolism and compensatory processes, also explaining the difference in results between subjects exposed to mixtures of organic solvents (Schreiber et al., 2002). Thus it is important from markers that make direct measurements of concentrations of organic solvents or their metabolites in the body.

We studied subjects chronically exposed to mixed solvents containing ketone, methyl ethyl ketone, 1,2 dichloroethane, butyl acrylate, methyl isobutyl ketone, toluene, n-butanal, acetone, ethyl benzene, xylene, styrene and cyclohexanone, performing measurements of mandelic acid, hippuric acid and methyl hippuric acid in urine (metabolites of styrene, toluene and xylene) and gas chromatography of urine samples (xylene). Results were correlated with the results of quantitative assessment of color vision with the vision and D15d contrast with the MCT 8000 Vistech. Methyluric acid concentration in urine was positively correlated with contrast sensitivity for spatial frequencies in which the subjects showed the greatest loss of contrast sensitivity (6 and 12 cpd) (Gong et al., 2003). These results are similar to those found by Campagna et al. (1995).

Another study sought to correlate with visual loss with urinary biomarker concentrations was carried out with residents of apartments with laundry and laundry employees exposed to tetrachloroethylene (tetrachloroethene, or perc). Color vision and contrast vision of these subjects were evaluated with the F.A.C.T. and the D15d, respectively. The marker was the measurement of environmental concentration of tetrachloroethylene and carbon dioxide in the air by gas chromatography with electron capture and biomarker concentrations were tetrachloroethylene, trichloroacetic acid, tetrachloroethane in urine samples by gas chromatography/mass spectrometry, tetrachloroethylene in the blood and breast milk by gas chromatography / mass spectrometry and tetrachloroethylene and carbon dioxide in exhaled air by gas chromatography with electron capture, and in the urine

of four workers were also measured other metabolites of tetrachlorethylene, creatinine, mercapturic acid and N-acetyl-S-(1,2,2-triclorovinil)-L-cysteine by gas chromatography / mass spectrometry. Positive correlations were observed, dose-dependent changes between the visual and environmental and biological markers (Schreiber et al., 2002).

In another study also observed a positive correlation between the color vision losses in workers exposed to styrene, D15d quantified with the environmental label taken as the concentration of styrene in the atmosphere and biomarker considered as the concentration of mandelic acid in urine (Eguchi et al., 1995).

The interference of alcoholic beverages and tobacco by individuals due to occupational exposure to organic solvents on the results of visual psychophysical tests

In the study of subjects chronically exposed to a mixture of solvents containing ketone, methyl ethyl ketone, 1,2 dichloroethane, butyl acrylate, methyl isobutyl ketone, toluene, n-butanal, acetone, ethyl benzene, xylene, styrene and cyclohexanone, and assessed by color vision and luminance contrast vision, we found that smoking affects the visual contrast sensitivity (Gong et al., 2003). A similar result was found by Eguchi et al. (1995). It was found no interference of smoking and consumption of alcoholic beverages in the evaluation of vision using D15d and MCT 8000 (Gong et al., 2003). In addition, workers in a petrochemical distillation factory exposed to solvent mixtures containing isopentane, hexane, heptane, octane, cyclohexane, methyl cyclohexane, benzene, toluene, xylene, ethyl benzene, 1,1,1-trichloroethane and methyl-tertiary-butyl ether, in painters exposed to toluene and in workers exposed to styrene assessed by color vision D15d, consumption of alcohol and smoking had no effect on the results of visual evaluation (Lee et al., 2007, Campagna et al., 2001, Eguchi et al., 1995).

Avaliação visual de sujeitos expostos de forma ocupacional a solventes orgânicos através de métodos psicofísicos

Resumo: Os solventes orgânicos são substâncias neurotóxicas que podem causar efeitos danosos sobre as funções visuais. É comum a exposição ocupacional a esses tipos de substâncias, pois elas apresentam grande aplicabilidade em inúmeras atividades. Os efeitos podem ser quantificados por testes psicofísicos. Os testes mais usa-

dos nesse tipo de avaliação são de ordenamento de matizes, como o Teste D15 Dessaturado de Lanthony e o Teste dos 100 Matizes de Farnsworth-Munsell, e avaliação de sensibilidade ao contraste espacial de luminância, como MCT 8000 Vistech, VCTS 6500 Vistech e FACT 101. Em geral esses testes descrevem perda de discriminação de cores, afetando tanto o eixo azul-amarelo quanto o eixo verde-vermelho, e diminuição da sensibilidade ao contraste de luminância principalmente para as frequências espaciais mais baixas. Existe correlação positiva entre os resultados da avaliação psicofísica e vários marcadores biológicos e ambientais, mas essa correlação depende do marcador e do tipo de solvente ao qual os indivíduos são expostos. Fatores como alcoolismo crônico e tabagismo inveterado podem interferir no processo de correlacionar esses resultados.

Palavras-chave: Solventes orgânicos. Exposição ocupacional. Psicofísica visual. Visão de cores. Sensibilidade ao contraste.

Evaluation visuelle par des méthodes psychophysiques de personnes soumises à une exposition professionnelle aux solvants organiques

Résumé: Les solvants organiques sont des substances neurotoxiques que peuvent causer des effets préjudiciables dans le système visuel. L'exposition professionnelle de ces types de substances est commune parce qu'ils sont utilisés dans une grande variété d'activités. Ces effets peuvent être quantifiés par des tests spécifiques de psychophysique. Les tests les plus utilisés dans cette évaluation sont, pour la vision des couleurs, le Lanthony Panel D-15 désaturé et le test Farnsworth-Munsell 100-Hue, et pour l'évaluation de la sensibilité au contraste, le MCT 8000 Vistech, le VCTS 6500 Vistech et le FACT 101. Généralement, ces tests révèlent une réduction de discrimination des couleurs, des effets dans les axes bleu-jaune et rouge-vert, et une diminution de sensibilité au contraste, spécialement dans les basses fréquences spatiales. Il y a une corrélation positive entre les résultats psychophysiques et les marqueurs biologiques environnementaux, mais cette corrélation dépend du marqueur et du type de solvant auquel le sujet a été exposé. Des facteurs tels que l'alcool et le tabac peut nuire à la corrélation des résultats.

Mots-clés: Solvants organiques. L'exposition Occupacional. Psychophysique Visual. Vision des couleurs. Sensibilité au contraste.

Evaluación visual mediante métodos psicofísicos de las personas sometidas a exposición laboral a solventes orgánicos

Resumen: Los solventes orgánicos son sustancias neurotóxicas que pueden causar efectos dañinos en el sistema visual. La exposición ocupacional a estas sustancias es común, ya que se utilizan en una amplia variedad de actividades. Estos efectos pueden ser cuantificados por las pruebas psicofísicas específicas. Las pruebas más utilizadas para la evaluación de la visión del color son las pruebas de acuerdo, tales como el Panel de Lanthony D-15 desaturado de prueba y la prueba de Farnsworth-Munsell 100-hue, y para evaluar la sensibilidad al contraste, pruebas impresas panel como el MCT 8000 VISTECH, VCTS 6500VISTECH, y el hecho 101 pruebas. En general, estas pruebas demuestran que las pérdidas de color la discriminación en el eje azul-amarillo y rojo-verde, y una disminución de la sensibilidad al contraste, sobre todo a bajas frecuencias espaciales. Hay una correlación positiva entre los resultados de estudios biológicos y psicofísicos marcadores del medio ambiente, pero esta relación depende de la marca y del tipo de disolvente para que los individuos estén expuestos. Factores tales como el alcohol y el tabaco pueden interferir con la correlación de los resultados.

Palabras clave: Disolventes orgánicos. Exposición Ocupacional. Psicofísica Visual. Visión del color. Sensibilidad al contraste.

References

Ahmadi, A., Jonsson, P., & Flodin, U. (2002). Interaction between smoking and glutathione S-transferase polymorphisms in solvent-induced chronic toxic encephalopathy. *Toxicology and Industrial Health, 18*, 289-296.

Amaducci, L., Arfaioli, C., Inzitari, D., & Marchi, M. (1982). Multiple sclerosis among shoe and leather workers: an epidemiological survey in florence. *Acta Neurologica Scandinavica, 65*, 94-103.

Amorim, L. C. A. (2003). Os biomarcadores e sua aplicação na avaliação da exposição aos agentes químicos ambientais. *Revista Brasileira de Epidemiologia, 6*, 1-13.

Baelum, J., Andersen, I., & Molhave, L. (1982). Acute and subacute symptoms among workers in the printing industry. *British Journal of Industrial Medicine, 39*, 70-75.

Baker, E. L. (1994). Review of recent research on helth effects of occupational exposure to organic solvents. *Journal of Occupational Medicine, 36*, 1079-1092.

Birch J. (2001). *Diagnosis of defective colour vision* (2nd ed.). Oxford, UK: Butterworth-Heinemann.

Boeckelmann, I., & Pfister, E. A. (2003). Influence of occupational exposure to organic solvent mixtures on contrast sensitivity in printers. *Journal of Occupational Environmental Medicine, 45*, 25-33.

Botelho de Souza, C. R. (1995). *Sistema de avaliação visual: análise orientada a objetos utilizando a metodologia OMT*. Trabalho de Conclusão de Curso de Graduação em Ciência da Computação, Centro de Ciências Exatas e Naturais, Universidade Federal do Pará Belém, PA.

Bowman, K. J. (1982). A method for quantitative scoring method the Farnsworth Panel D-15. *Acta Ophtalmologica, 60*, 907-916.

Braga, A. M. (1996). *Aplicação combinada dos métodos de Booch e OOSE na modelagem de um Software para avaliação psicofísica da capacidade de discriminação de cores*. Trabalho de Conclusão de Curso de Graduação em Ciência da Computação, Centro de Ciências Exatas e Naturais, Universidade Federal do Pará, Belém, PA.

Campagna, D., Mergler, D., Huel, G., Belanger, S., Truchon, G., & Ostiguy, C. (1995). Visual dysfunction among styrene-exposed workers. Scandinavian *Journal of Work, Environment & Health, 21*, 382-390.

Campagna, D., Stengel, B., Mergler, D., Limasset, J. C., Diebold, F., Michard, D. et al. (2001). Color vision and occupational toluene exposure. *Neurotoxicology and Teratology, 23*, 473-480.

Chancellor, A. M., Slattery, J. M., Fraser, H., & Warlow, C. P. (1993). Risk factors for motor neuron disease: A case-control study based on patients from the Scottish Motor Neuron Disease Register. *Journal of Neurology, Neurosurgery and Psychiatry, 56*, 1200-1206.

Dick, F., Semple, S., Osborne, A., Soutar, A., Seaton, A., Cherrie, J. W. et al. (2002). Organic solvent exposure, genes, and risk of neuropsychological impairment. *Quarterly Journal of Medicine, 95*, 379-387.

Dick, F., Semple, S., Soutar, A., Osborne, A., Cherrie, J.W., & Seaton, A. (2004). Is colour vision impairment associated with cognitive impairment in solvent exposed workers? *Journal of Occupacional and Environmental Medicine, 61*, 76-78.

Eguchi, T., Kishi, R., Harabuchi, I., Yuasa, J., Arata, Y., Katakura, Y. et al. (1995). Impaired colour discrimination among workers exposed to styrene: relevance of a urinary Metabolite. *Occupational and Environmental Medicine, 52*, 534-538.

Fallas, C., Fallas, J., Maslard, P., & Dally, S. (1992). Subclinical impairment of colour vision among workers exposed to styrene. *British Journal of Industrial Medicine, 49*, 679-682.

Farnsworth, D. (1943). The farnsworth-munsell 100-Hue and dichotomous tests for color vision. *Journal of the Optical Society of America, 33*, 568-578.

Farnsworth, D. (1957). *The farnsworth-munsell 100-Hue test for the examination of Color Discrimination (Manual)*. Baltimore: Kollmorgen.

Flodin, U., Söderfeldt, B., Noolind-Brage, H., Fredriksson, M., & Axelson, O. (1988). Multiple scleroses, solvents and pets. A case referent stud.*Archives of Neurology, 45*, 620-623.

Geller, A. M., & Hudnell, H. K. (1997). Critical issues in the use and analysis of the Lanthony Desaturete Color Vision test. *Neurotoxicology and Teratology, 19*, 455-465.

Gong, Y., Kishi, R., Kasai, S., Katakura, Y., Fujiwara, K., Umemura, T. et al. (2003). Visual dysfunction in workers exposed to a mixture of organic solvents. *NeuroToxicology, 24*, 703-710.

Graham, A. J., Macdonald, A. M., & Hawkes, C. H. (1997). British motor neuron disease twin study. *Journal of Neurology, Neurosurgery and Psychiatry, 62*, 562-569.

Gregersen, P., Angelso, B., Nielsen, T. E., Norgaard, B., & Uldal, C. (1984). Neurotoxic effects of organic solvents in exposed workers: An occupational, neuropsychological and neurological investigation. *American Journal of Industrial Medicine, 5*, 201-205.

Gregersen, P., Klausen, H., & Elsnab, U. C. (1987). Chronic toxic encephalopathy in solvent-exposed painters in Denmark 1976-1980: Clinical cases and social consequences after a 5 year follow up. *American Journal of Industrial Medicine, 11*, 399-417.

Gunnarsson, L. G., Bodin, L., Söderfeldt, B., & Axelson, O. (1992). A case-control study of neurone motor disease: Its relation to heritability, and occupational exposures, particularly to solvents. *British Journal of Industrial Medicine, 49*, 791-798.

Hänninen, H., Eskelinen, L., Husman, K., & Nurminen, M. (1976). Behavioral effects of long term exposure to a mixture of organic solvents. *Scandinavian Journal of Work, Environmental & Health, 4*, 240-255.

Herpin, G., Gargouri, I., Gauchard, G. C., Nisse, C., Khadhraoui, M., Elleuch, B., et al. (2009). Effect of chronic and subchronic organic solvents exposure on balance control of workers in plant manufacturing adhesive materials. *Neurotoxicity Research, 15*,179-186.

Horan, J. M., Kurt, T. L., Landrigan, P. J., Melius, J. M., & Singal, M. (1985). Neurologic dysfunction from exposure to 2-t-butylazo-2-hydroxy-5-methylhexane (BHMH): A new occupational neuropathy. *American Journal of Public Health, 75*, 513-517.

Ihrig, A., Nasterlack, M., Dietz, M. C., Hoffmann, J., & Triebig, G. (2003). Pilot study on prevalence of color vision dysfunction in long-term solvent-exposed painters. *Industrial Health, 41*, 39-42.

Iregren, A., Anderson, M., & Nylen, P. (2002). Color vision and occupational chemical exposures: II Visual functions in non-exposed subjects. *NeuroToxicology, 23*, 35-45.

Isserver, H., Malat, G., Sabuncu, H. H., & Yuksel, N. (2002). Imparirment of colour vision in patients with n-hexane exposure-dependent toxic polyneuropaty. *Journal of Occupational and Environmental Medicine, 52*, 183-186.

Lacerda, E. M. C. B. (2010). *Avaliação psicofísica visual cromática e acromática de sujeitos expostos de forma crônica ocupacional à mistura de solventes orgânicos*. Dissertação de Mestre em Ciências, Programa de Pós-graduação em Neurociências e Biologia Celular, Instituto de Ciências Biológicas, Universidade Federal do Pará, Belém, PA.

Lacerda, E. M. C. B., Lima, M. G., Souza, G. S., Rodrigues, A. R., Teixeira, C. E. C., Ventura, D. F. et al. (2008). Avaliação psicofísica de pessoas expostas de modo crônico ocupacional a solventes orgânicos: sensibilidade ao contraste espacial e temporal de luminância, discriminação de cores e perimetria estática de humphrey. *Anais do I Congresso IBRO / LARC de Neurociências da América Latina, Caribe e Península Ibérica*. Búzios, Rio de Janeiro.

Lacerda, E. M. C. B., Souza, G. S., Rodrigues, A. R., & Silveira, L. C. L. (2009). Neurotoxicidade dos solventes orgânicos. *Neurociências, 5*, 165-173.

Lacerda, E. M. C. B., Lima, M. G., Souza, G. S., Rodrigues, A. R., Teixeira, C. E. C. Barata, L. J. et al. (2010). Chromatic and achromatic psychophysical evaluations from chronically exposed workers to mixture of mixture of organic solvents. The

Association for Research in Vision and Ophthalmology (ARVO). Annual Meeting Abstract Search and Program Planner, Fort Lauderdale, Florida. *Investigative Ophthalmology & Visual Science, 51*, E-Abstract 6303/D975.

Lee, E.-H., Eum, K. D., Cho, S.-I., Cheong, H.-K., & Paek, D. M. (2007). Acquired dyschromatopsia among petrochemical industry workers exposed to benzene. *NeuroToxicology, 28*, 356-363.

Lee, S. H., & Lee, S. H. (1993). A study on the neurobehavioral effects of occupational exposure to organic solvents in Korean workers. *Environmental Research, 60*, 227-232.

Lemasters, G. K., Livingston, G. K., Lockey, J. E., Olsen, D. M., Shukla, R., New, G. et al. (1997). Genotoxic changes after low-level solvent and fuel exposure on aircraft maintenance personnel. *Mutagenesis, 12*, 237-243.

Linz, D. H., De Garmo, P. L., Morton, W. E., Wiens, A. N., Coull, B. M., & Maricle, R. A. (1986). Organic solvent induced encephalopathy in industrial painters. *Journal of Occupational Medicine, 28*, 119-125.

Mergler, D., & Blain, L., (1987). Assessing color vision loss among solvent-exposured workers. *American Journal of Industrial Medicine, 12*, 195-203.

Mergler, D., Belanger, S., De Grosbois, S., & Vachon, N. (1988). Chromal focus of acquired chromatic discrimination loss and solvent exposure among printshop workers. *Toxicology, 49*, 341-348.

Mergler, D., Bowler, R., & Cone, J. (1990). Colour vision loss among disabled workers with neuropsychological impairment. *Neurotoxicology & Teratology, 12*, 669-672.

Mikkelsen, S. (1980). A cohort study of disability pension and death among painters with special regard to disabling presenile dementia as an occupational disease. *Scandinavian Journal of the Society Medical, 16*, 34-43.

Morrow, L. A., Ryan, C. M., Goldstein, G., & Hodgson, M. J. (1989). A distinct pattern of personality disturbance following exposure to mixtures of organic solvents. *Journal of Occupational Medicine, 31*, 743-746.

Muttray, A., Wolters, V., Mayer-Popken, O., Schicketanz, K. H., & Knietzko, J. (1995). Effect of subacute occupational exposure to toluene on color vision. *International Journal of Occupational Medicine and Environmental Health, 8*, 339-345.

National Occupational Health and Safety Commission. (1990). *Industrial organic solvents*. Australia: Alken Press Pty.

Olsen, J., & Sabroe, S. (1980). A case-reference study of neuropsychiatric disorders among workers exposed to solvents in the danish wood and furniture industry. *Scandinavian Journal of the Society Medical, 16*, 44-49.

Occupational Safety and Health Information Series. (1998). *Chronic organic solvent neurotoxicity. Diagnostic criteria*. New Zealand: Author.

Päällysaho, J., Näsänen, R., Mäntyjärvi, M., Kaukiainen, A., & Sainio, M. (2007). Colour vision defects in occupational chronic solvent encephalopathy. *Human & Experimental Toxicology, 26*, 375-383.

Pfister, E., Böckelmann, I., Darius, S., & Wurthmann, C. (1999). Einbeziehung psychopathologischer verfahren zur objektivierung von neurotoxischen früheffekten durch blei und lösemittelgemische. *Fortschritte der neurologie-psychiatrie, 67*, 435-440.

Rodrigues, A. R. (2003). *O desenvolvimento de aplicativos de avaliação psicofísica visual em estações de trabalho IBM RISC 6000*. Dissertação de Mestrado em Ciências, Programa de Pós-graduação em Ciências Biológicas, Centro de Ciências Biológicas, Universidade Federal do Pará, Belém, PA.

Rodrigues, A. R., Souza, C. R. B., Braga, A. M., Rodrigues, P. S. S., Silveira, A. T., Damin, E. T. B. et al. (2007). Mercury toxicity in the Amazon: Contrast sensitivity and color discrimination of subjects exposed to mercury. *Brazilian Journal of Medical and Biological Research, 40*, 415-424.

Rosen, J. A. (1965). Pseudoisochromatic visual testing in the diagnosis of disseminated sclerosis. *Transactions of the American Neurological Association, 90*, 283-284.

Rosenberg, N. (1989). Nervous system effects of toluene and other organic solvents. *Western Journal of Medicine, 5*, 571-572.

Schreiber, J. S., Hudnell, H. K., Geller, A. M., House, D. E., Aldous, K. M., Force, M. S. et al. (2002). Apartment residents' and day care workers' exposures to tetrachloroethylene and deficits in visual contrast sensitivity. *Environmental Health Perspective, 110*, 655-664.

Schulte, P. A., Burnett, C. A., Boeniger, M. F., & Johnson, J. (1996). Neuro degenerative diseases: Occupational occurrence and potencial risk factors 1982 through 1991. *American Journal of Public Health, 86*, 1281-1288.

Semple, S., Dick, F., Osborne, A., Cherry, J. W., Souttar, A., Seaton, A. et al. (2000). Impairment of colour vision in workers exposed to organic solvents. *Journal of Occupational and Environmental Medicine, 57*, 582-587.

Silveira, L. C. L., Damin, E. T. B., Pinheiro, M. C. N., Rodrigues, A. R., Moura, A. L. A., Côrtes, M. I. T. et al. (2003). Visual dysfunction following mercury exposure by breathing mercury vapour or by eating mercury-contaminated food. In: J. D. Mollon, J. Pokorny & K. Knoblauch (Eds.), *Normal and defective colour vision* (pp. 407-417). Oxford, England: Oxford University Press.

Smargiassi, A., Mutt, A., De Rosa, A., De Palma, G., Negrotti, A., & Calzetti, S. (1999). A case-control study of ocupational and enviromental risk factors for Parkinson´s disease in the Emilia-Romagna region of Italy. *Neurotoxicology, 19*, 709-712.

Söderkvist, P., Ahamadi, A., & Akerback, A. (1996). Glutathione S-transferase M1 null genotype as a risk modifier for solvent-induced chronic toxic encephalopathy. *Work, Environment & Health, 22*, 360-363.

Verriest, G. (1963). Further studies on acquired deficiency of colour discrimination. *Journal of the Optical Society of America, 53*, 185-95.

Viaene, M., Vermeir, G., & Godderis, L. (2009). Sleep disturbances and occupational exposure to solvents. *Sleep Medicine Reviews, 13*, 235-243.

Eliza Maria da Costa Brito Lacerda, Professor at the After-Graduation Program in Neurosciences and Cellular Biology, Biological Sciences Institute, Federal University of Pará. Address: Av. Generalíssimo Deodoro, 92, Umarizal. Zip Code: 66055-240, Belém, Pará. E-mail:eliza_lacerda@yahoo.com.br

Dora Fix Ventura, Professor at the Psychology Institute, University of São Paulo. Address: Av. Professor Mello Moraes, 1721, Cidade Universitária. Zip Code: 00508-030, São Paulo, SP. E-mail: dventura@usp.br

Luiz Carlos de Lima Silveira, Professor at the Center for Tropical Medicine and the Biological Sciences Institute, Federeal University of Pará. Address: Av. Generalíssimo Deodoro, 92, Umarizal. Zip Code: 66055-240, Belém, Pará. E-mail: luiz@ufpa.br

Received: 21/10/2010
Accepted: 06/12/2010