Alcohol & Alcoholism Vol. 33, No. 2, pp. 168–172, 1998

REDUCED BINOCULAR DEPTH INVERSION IN PATIENTS WITH ALCOHOLISM

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(*Received* 28 *July* 1997; *in revised form* 23 *October* 1997; *accepted* 28 *October* 1997)

Abstract — Binocular depth inversion represents an illusion of visual perception, serving to invert the perception of implausible hollow objects, e.g. a hollow face into a normal face. Such inversion occurs frequently, especially when objects with a higher degree of familiarity (e.g. photographs of faces) are displayed. Cognitive factors are assumed to override the binocular disparity cues of stereopsis. The hypothesis was tested that during mild and moderate alcohol withdrawal, and severe and mild alcohol intoxication, the central nervous system is unable to correct implausible perceptual hypotheses. Measurements of binocular depth inversion in perception of three-dimensional objects were performed in 10 patients with severe alcohol intoxication, in 10 subjects with mild alcohol intoxication, in nine patients with moderate alcohol withdrawal treated with carbamazepine, in 10 patients with moderate alcohol withdrawal without any pharmacological treatment, in 11 patients with mild alcohol withdrawal and in 10 healthy volunteers. The binocular depth inversion scores were highly elevated in the severely intoxicated patients group and in the group with moderate withdrawal symptoms without carbamazepine treatment, in comparison to the healthy volunteers. The data demonstrate a strong impairment of binocular depth inversion in moderate alcohol withdrawal and during severe alcohol intoxication. This supports the view that these states may be accompanied by a disorganization of the interaction between sensory input and top-down component. The effects of carbamazepine are discussed.

INTRODUCTION

The acute effects of alcohol range from excitement to stupor and coma. These effects are modified by the rapidity of increase in blood alcohol levels, history of alcohol intake, and the psychosocial setting in which consumption occurs. Alcohol intoxication can be associated with clouding of consciousness, impaired cognitive functions, anxiety, and illusions. Additionally, during the first days of abstinence, most alcohol misusers exhibit physical signs of withdrawal and many go through a stage with hallucinations and delusions. To explain psychotic symptoms like hallucinations and illusions, Broadbent (1958) proposed a model of information processing in perception, according to which the data transmission system has a limited capacity for the amount of information which can be transmitted. He furthermore suggested the existence of a 'filter' which selects the information flow from the sensory input to the 'limited capacity channel (p-system)'. According to the current view, perception is not a singular process; rather it is assumed to result from interaction between different subsystems. Two components of the sensory system have to be considered, the 'bottom-up' component and an additional 'top-down' component (Wallbott and Ricci-Bitty, 1993; Cauller, 1995). The results of such interactions between these two components are sometimes ambiguous. Alternative interpretations may be possible and thus may lead to internal interpretational conflicts. A decision could possibly be reached by the activity of a third component, a 'censor' (Emrich, 1988). This assumed third component has to perform decisions in ambiguous situations. This leads to an adjustment of possible contents of perception to actual contexts, as well as to memory data regarding experiences that were acquired in the past by the system. The interaction between the above-men-

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tioned components is assumed to be responsible for a biologically significant and meaningful internal representation of the external world during perception.

Human vision acquires information about three-dimensional (3-D) shape from a number of different sources. Binocular vision, motion parallax, texture gradients, outline contour, lighting direction, and shading all contribute information about 3-D shape (Ramachandran, 1988; Hill and Bruce, 1993). The visual information available from scenes of the natural world is encapsulated, to a large degree, by the geometric relationship between 3-D solid objects and their projections into the two retinal images. The above-mentioned perceptual cues for 3-D shape are used by human observers. These cues are created by transformation of the geometric information by spatial or temporal displacement of the vantage point or the viewed object in the cases of motion and stereo, and by the link between surface properties and geometry in the cases of shading, texture, and specularities. The interaction between these different cues for 3-D shape is still an unsolved problem. Wheatstone (1838) first identified a source of information used by human vision to obtain a 3-D shape, the binocular disparity. It relies on the horizontal retinal disparity between the images of an object projected onto the two retinas. In 1852 Wheatstone reported that when the disparity of objects is reversed by interchanging the view of the left and right eye ('pseudoscopy'), apparent depth is also reversed.

Left and right eye information remains segregated in different layers of the lateral geniculate nucleus. The earliest stage of processing showing binocular responsiveness is V1, the primary visual cortex, where many simple and complex cells are driven by input from both eyes (Hubel and Wiesel, 1970; Clarke and Whitteridge, 1977; Poggio and Poggio, 1984). Among these cells, some respond maximally when their optimal stimuli fall onto disparate areas of the two retinas (Hubel and Wiesel, 1970). Early evidence suggested that selectivity for disparity was found only in V2, but it is now established that disparity-selective cells do exist in the primary visual cortex (Poggio and Poggio, 1984). As a code for disparity, the firing rate of a single V1 or V2 cell is ambiguous because it varies with factors such as contrast and speed, as well as disparity. Visual processing in primates involves distinct areas in the cerebral cortex plus several major subcortical centres. Anatomical and physiological evidence indicates that these structures are arranged in a hierarchy that includes several stages of cortical processes as well as subcortical stages. At each stage of the hierarchy, there is evidence for concurrent processing streams. Substantial cross-talk occurs between streams at any stage of the hierarchy. This convergence and divergence may provide the flexibility needed for the visual system (Van Essen *et al.*, 1992).

Yellot (1981) demonstrated stereoscopic visual experience to be the result of a process in which the brain tests hypotheses about the 3-D shape of objects against the evidence provided from their retinal representations. Binocular depth inversion occurs frequently with hollow 3-D objects. Such inversion is particularly evident when photographs of faces are displayed. Normal depth is perceived when they are viewed pseudoscopically. The resistance to reversal of depth has been attributed to familiarity with the shape of objects (Gregory, 1973). Hill and Bruce (1993, 1994) have shown experimentally that both the familiarity of faces and a general preference for convexity tend to favour the illusory, face-like interpretation of the hollow mask. The current paper has tested the hypothesis that the 'equilibrium' between the above-mentioned perceptual components may be disturbed during alcohol withdrawal and alcohol intoxication, resulting in an impairment of binocular depth inversion.

METHODS

The method used has been described previously (Schneider *et al.*, 1996; Emrich *et al.*, 1997). Ten patients with severe alcohol intoxication (group 1, mean age ± SD: 38.1 ± 5.8 years, 1 female, 9 males), 10 patients with moderate alcohol withdrawal (group 2, mean age ± SD: 36.8 ± 4.8 years, 4 females and 6 males), 9 patients with moderate alcohol withdrawal treated with carbamazepine (group 3, mean age ± SD: 46.5 ± 13.5 years, 3 females, 6 males), 11 patients with mild alcohol withdrawal (group 4, mean age ± SD: 38.8 ± 7.8 years, 3 females and 8 males), 12 subjects with a mild alcohol intoxication (group 5, mean age ± SD: 25.9 ± 1.9 years, 10 males), and 10 healthy volunteers (group 6, mean age

32.3 ± 8.1 years, 3 females, 8 males) as a control group all participated in the study. All subjects underwent a physical examination before starting the investigation and gave their informed consent prior to their inclusion in the study. The patients had been consecutively admitted to the psychiatric unit at the Medical School, Hannover. The control group was recruited from hospital medical staff. Subjects were asked about intake of psychopharmacological medication and pharmacological agents that might interfere with visual function and their psychiatric history, and were excluded from the study if there was a positive response.

The patients in alcohol withdrawal were tested with the CIWA-Ar-scale (Sullivan *et al.*, 1989). This is a 10-item scale for clinical quantification of the severity of alcohol withdrawal. The maximum possible score was 67 points. Eleven patients in mild withdrawal had low scores (<10) and had no pharmacological treatment. Patients in moderate alcohol withdrawal (withdrawal scores >10) received either a pharmacological treatment with carbamazepine (10 to 15 mg/kg/day orally) or no pharmacotherapy during the experiments. Ten severely alcohol intoxicated patients had blood alcohol levels >200 mg/dl and 12 subjects with mild intoxication had blood alcohol levels between 30 and 35 mg/dl. All the patients had received a diagnosis of alcohol dependence according to DSM-IV and ICD-10 criteria. In the Munich Alcoholism Test, the German version of the Michigan Alcoholism Screening Test (MAST), each patient fulfilled the criteria for alcohol dependence. Patients with a concurrent withdrawal from other drugs (e.g. benzodiazepines, barbiturates, cocaine, opiates, amphetamines, cannabis), or history of psychotic disorders were excluded. Before the investigation was started, patients underwent psychiatric exploration and ophthalmological examination. Visual acuity was measured using a Snedden chart, reading at a distance of 6 m. Each eye was tested separately. Subjects were included in the study only if their vision was 6/6 or better without glasses.

It is possible to create strong depth impressions from pictures by sending the view the eye would see if an actual object in depth was presented to each eye separately (Wheatstone, 1838). To produce this effect, the following technique was used: 12 different picture sets were presented in a random order on a display. With an arrangement of mirrors in front of the display — distance 0.4 m (analogous to Wheatstone's stereoscope), the left eye view (left picture) was sent to the left eye of the subject and the right eye view to the right eye. The result was that the subject saw a single 3-D object in the middle of the display. The resulting perceptions of 3-D objects are of course illusory. Pseudoscopy was induced by exchanging the pictures from the left side of the display to the right side and vice versa. Each picture set was displayed for 30 s. As a control paradigm to exclude response bias effects, picture sets were displayed in random order either reversed from left to right and vice versa, or not reversed. Before commencement of the study, stereopsis was investigated using the stereo test: house fly and circles (Stereo Optical Co., Chicago, USA), and the TNO test for stereoscopic vision (Lameris, Utrecht, The Netherlands) and had to amount to at least 60 s of arc in each subject.

Patients and volunteers described their visual experiences during pseudoscopic projection of 12 picture sets, e.g. flowers, house upside down, garden chair upside down, teddy masks, human faces, and human faces upside down. Three picture sets were projected in an upside down orientation because inhibition of the binocular depth inversion was found to be facilitated by this (Wolf, 1985).

An operationalized description of four criteria within every picture in the middle of the display is given which characterizes the binocular depth perception of special parts of the object (i.e. description of nose, eyes, cheeks, chimney etc.). For example: Is the nose of the face orientated towards the observer or away from him? A maximal score of 8 points (=100%) is reached on each picture if the criterion is identified within 30 s.

In an earlier study, 20 healthy volunteers (medical students, 10 males and 10 females) were investigated with similar pictures. The pictures were displayed between 07:00 and 08:00 and again between 20:00 and 21:00. There were no significant differences between males and females and no indication of a circadian rhythm in the binocular depth inversion. From these 20 subjects, two females had a headache and one female and one male had a cold during the measurements. These subjects did not have significantly different inversion scores (data unpublished).

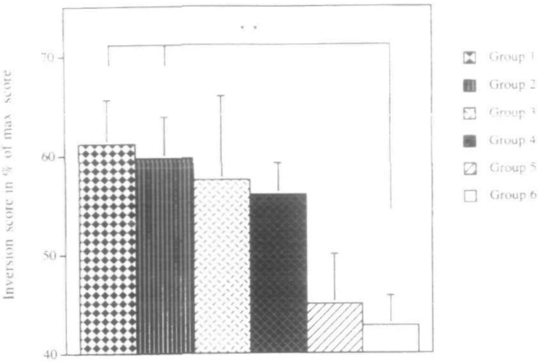

Fig. 1. Binocular depth inversion scores in controls and various alcohol patients.
Inversion scores in severely alcohol-intoxicated patients (group 1), patients with moderate alcohol withdrawal (group 2), with moderate alcohol withdrawal and treated with carbamazepine (group 3), with mild alcohol withdrawal (group 4), with mild alcohol intoxication (group 5), and in healthy volunteers (group 6) were measured. The results are given as the means ± SD (bars) for groups, the numbers in which are given in the Methods section. $^{**}P < 0.01$ (Mann–Whitney two-tailed test) vs the control group.

RESULTS

The results are described in Fig. 1. The average scores of the severely-intoxicated patient group and the patient group with moderate alcohol withdrawal without any medication were highly elevated, in comparison with those of the healthy volunteers. The differences were statistically significant (Mann–Whitney test, two-tailed, $P < 0.01$). The patient group with mild alcohol withdrawal, the mildly intoxicated subjects, and the patient group with moderate alcohol withdrawal and carbamazepine treatment showed no significant inversion score differences in comparison with the control group. When visual information was displayed to the correct eye, there were no significant differences between the scores of the different patient groups and the control group. These results reflect the reduced binocular depth inversion of patients with moderate alcohol withdrawal and patients with severe alcohol intoxication.

DISCUSSION

Visual illusions have already been used in studies into psychopathology and abnormalities of perception in psychiatric patients. In the present study, the binocular depth inversion in patients suffering from alcohol intoxication, alcohol withdrawal, and in healthy volunteers was investigated. The advantage of testing binocular depth inversion is that it allows for an evaluation of the function between the sensory data (bottom-up component) and the top-down component. The results support the view that some of the perceptual phenomena during alcohol withdrawal and alcohol intoxication may be explained by a disorganization of the interaction between generation of perceptual hypotheses (top-down component) and sensory data.

Huxley (1954), Malenka *et al.* (1982) and Frith and Done (1988, 1989) assumed a deficiency of internal correcting and adaptive systems or an imbalance in relation to the generation of concepts during a psychotic state. Moderate alcohol withdrawal and severe alcohol intoxication also tend to weaken an internal 'censor', which is relevant for perceptional processes.

During mild alcohol withdrawal and mild intoxication the supposed imbalance of the perception-regulating systems is not obvious. Additionally, carbamazepine in therapeutic doses seems to reduce the system imbalance during moderate alcohol withdrawal, insofar as the expected impaired binocular depth inversion is not as pronounced as it is without carbamazepine. An interesting aspect of carbamazepine action on the brain is the apparent selectivity for the limbic system, a feature that may provide an anatomical basis for both the psychotropic action of the drug and its efficacy in psychomotor epilepsy (Wada, 1977; Post *et al.*, 1992). If carbamazepine improves the impaired binocular depth inversion, the system imbalance may be represented in limbic structures. This is in line with the concept of the hippocampus appearing to control the processing of sensory input, consolidation, storage, retrieval, and regulation with motivational influences into complex cortical functions during the development of acquired behaviour (Gray and Rawlins, 1986; Olton, 1989). Hippocampal structures play an important part in generating predictions about plausible sensory inputs from the outer world and in comparing these predictions with actual inputs (Gray and Rawlins, 1986).

In conclusion, the binocular depth inversion test could possibly be a relatively sensitive test of the psychotropic activity of psychedelic and psychotogenic compounds, as well as of the presence of a psychotic state. From this viewpoint, binocular depth inversion is assumed to represent not a diagnostic test of a disorder, but to monitor a final pathway which is characterized by an impairment of systems regulating perception (Schneider *et al.*, 1996). From a practical standpoint, this test is not suitable to measure visual perception, e.g. in intoxicated car drivers because mild alcohol intoxication did not impair binocular depth inversion. This test seems to be more sensitive in measuring 'propsychotic states' (Emrich *et al.*, 1997; Sternemann *et al.*, 1997). Further experiments will focus on binocular depth inversion in patients with psychotic symptoms (e.g. hallucinations) before, during, and after alcohol withdrawal.

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