THE EFFECTS OF ALCOHOL ON THE VISUAL AND OCULAR MOTOR SYSTEMS

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Abstract

Alcohol is generally considered to be a central nervous system (CNS) depressant. This effect is progressive from higher cortical centres through to fundamental body functions. The effect of alcohol ingestion on the visual and ocular motor systems of ten healthy subjects was the basis of this study. Significant changes in the following, resulted from the ingestion of 0.375 g/kg body weight of 10% ethanol alcohol:

(i) prism measurements of deviations for near and distance
(ii) ocular movements
(iii) convergence near point
(iv) visual acuity at 6 m

No significant change was observed following testing of stereopsis or near visual acuity.

Key words: *ethanol alcohol, deviation, convergence near point, stereopsis, ocular motility, visual acuity.*

INTRODUCTION

Alcohol is generally considered to be a central nervous system depressant (CNS), having properties in common with general anaesthetic substances, appearing to depress the midbrain reticular activating system.[1]

Generally the depressant effect is progressive from higher cortical centres (thinking, learning, remembering and making judgement) to more fundamental functions of the body (speech, gait, perceptions and discriminations).

The effect of alcohol on the brain is rather biphasic in that low concentrations serve as a stimulant of certain functions which become progressively more depressed as the concentration increases. Depression of the cortical centres that control muscular activity will not only manifest itself in a reduced sense of balance, staggering gait and slurred speech, but also it is likely that uncoordination of extrinsic and intrinsic ocular muscles will result from depression of the reticular activating system and paramedian pontine reticular formation.

Much has been written about the effects of alcohol on eye movements. Wilkinson[2] reports a reduction in peak saccadic velocity and interruptions to smooth pursuit movements with increasing blood alcohol concentrations (BAC). Cogan and others[3-5] have outlined the tendency with inceasing BAC for heterophorias to become more esophoric for distance fixation and more exophoric for near.

In his profile of the alcoholic driver, Reynolds[6] presents studies that suggest a reduction in intraocular pressure, changes in dynamic visual acuity, sinusoidal and oculomotor tracking, as well as colour discrimination and peripheral gaze nystagmus with increasing BAC. Changes in visual search behaviour became evident with increasing concentrations as did decreased

This paper was written whilst the author was a third year student in Orthoptics at the Cumberland College of Health Sciences, N.S.W.

sensitivity to contrast at low levels of illumination.

Other studies[7-9] have related normal visual acuity and slowing of visual evoked potentials following alcohol ingestion.

It appears that little if any research has been undertaken involving changes to stereopsis, convergence or ocular motility resulting from the ingestion of specific quantities of alcohol.

This study therefore examines the effects of alcohol ingestion on the prism measurement for near and distance deviations, visual acuity near and distance, stereopsis, convergence and ocular motility.

METHOD

A total of ten healthy subjects (five male and five female) were chosen. All were members of a local volleyball team and partook in a regular fitness program. All were aged between 19 and 28 (mean 21.5) and weighed between 45 and 101 kg (mean 70.4). None were under any form of medication and all had moderate drinking habits.

The experiment was undertaken in the Psychopharmacological Research Unit of the Rozelle Hospital under the supervision of Professor Graham Starmer of the University of Sydney.

Subjects were instructed to consume a light non-fatty breakfast two hours prior to their stated drinking time and requested not to smoke on the morning of the experiment until all measurements had been completed.

Each subject was weighed five minutes prior to stated drinking time and given a dosage of 0.375 g/kg body weight of 10% ethanol alcohol (v/v EtoH) in orange juice (unsweetened, no preservatives or additives). Twenty minutes drinking time was allowed immediately after which two measures of breath alcohol concentrations (BAC) were taken using the Intoximeter IV (gas chromatograph type) and the Intoximeter 3000 (infra-red type). Alcohol dosage resulted in a mean level of 0.052% and 0.047% respectively which would be approximately 0.010% to 0.015% lower than actual blood levels. A constant blood:breath alcohol ratio is assumed throughout this study.

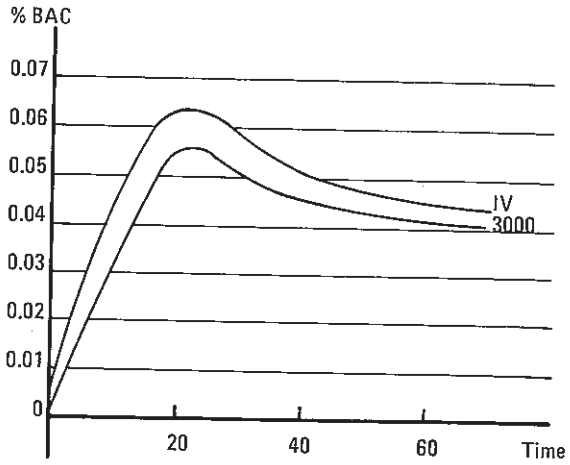

FIG 1: Mean BAC

Control measurements were taken prior to alcohol ingestion (T0) then at twenty minute intervals post-ingestion for one hour (T20, T60). Subjects' near and distance deviations were measured with prisms using an accommodative controlled target. Ocular movements were studied using a torch and an opaque occluder and, depending upon the presence of any change, graded according to whether this change was slight, moderate or large. The convergence near point (CNP) was measured using the RAF Rule and note was made as to the presence of voluntary convergence. Stereopsis was tested

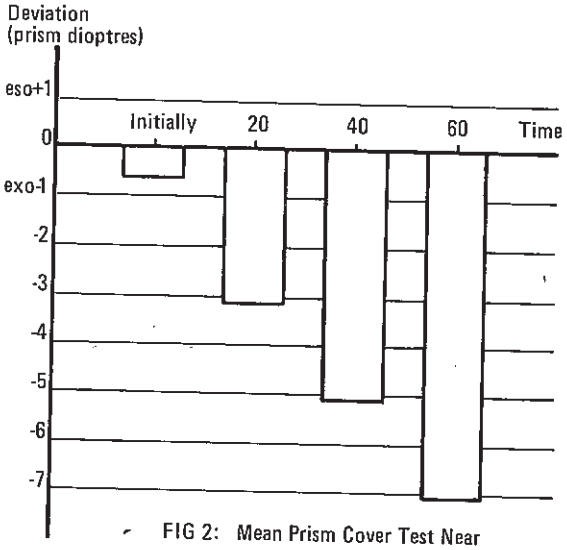

FIG 2: Mean Prism Cover Test Near

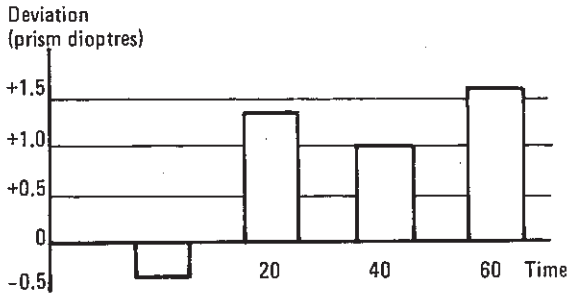

FIG 3: Mean Prism Cover Test Distance

using the TNO Random-Dot Stereo test and was performed at 33 cm under a strong light. Visual acuity was tested at both 1/3 m and 6 m, monocularly and binocularly using Snellen's test type for distance and Moorfields Bar Reading Book for near.

RESULTS

Figure 1 shows the mean BAC recorded on the subjects using both the Intoximeter IV and the Intoximeter 3000. The graph can be seen to consist of an ascending period to a peak at about T20 then gradually descending values until theoretically at approximately three hours post-ingestion the BAC will be back to zero.

An analysis of variance (at p 0.01 level) was carried out on mean prism measurements for near and distance deviations. A significant increase in mean near exophoric measures

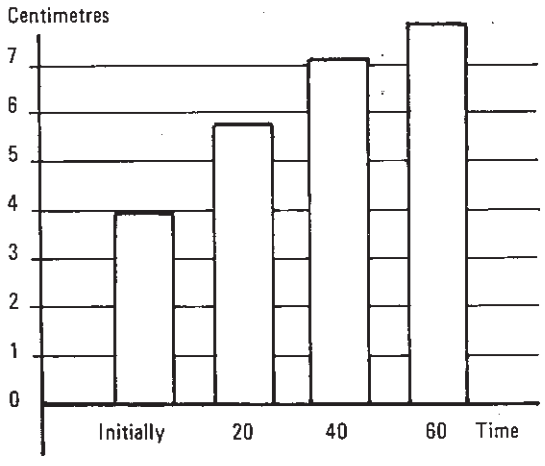

FIG 4: Mean Convergence Near Point

(Figure 2) and mean distance esophoric measures (Figure 3) was found over the specified time period (occasions).

The mean CNP over occasions is shown in Figure 4. An analysis of variance reveals a significant decrease in the mean standard over T0 to T60 (p 0.01).

An analysis of variance for changes in mean stereopsis over occasions was not significant at the 0.01 or 0.05 levels.

Changes in mean distance visual acuity were significant at the 0.05 level (see Figure 5)

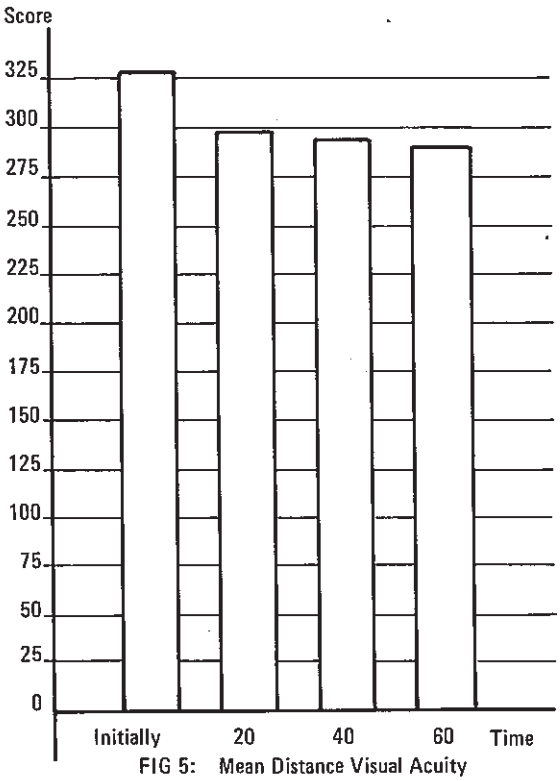

FIG 5: Mean Distance Visual Acuity

using

VA	6/5	6/6	6/9
Score	18	11	5

showing a reduction in visual acuity with increasing BAC over occasions. Near visual acuity however remained constant (N5 right, left and binocularly) throughout the study.

Changes in ocular movements over occasions are shown in Figure 6.

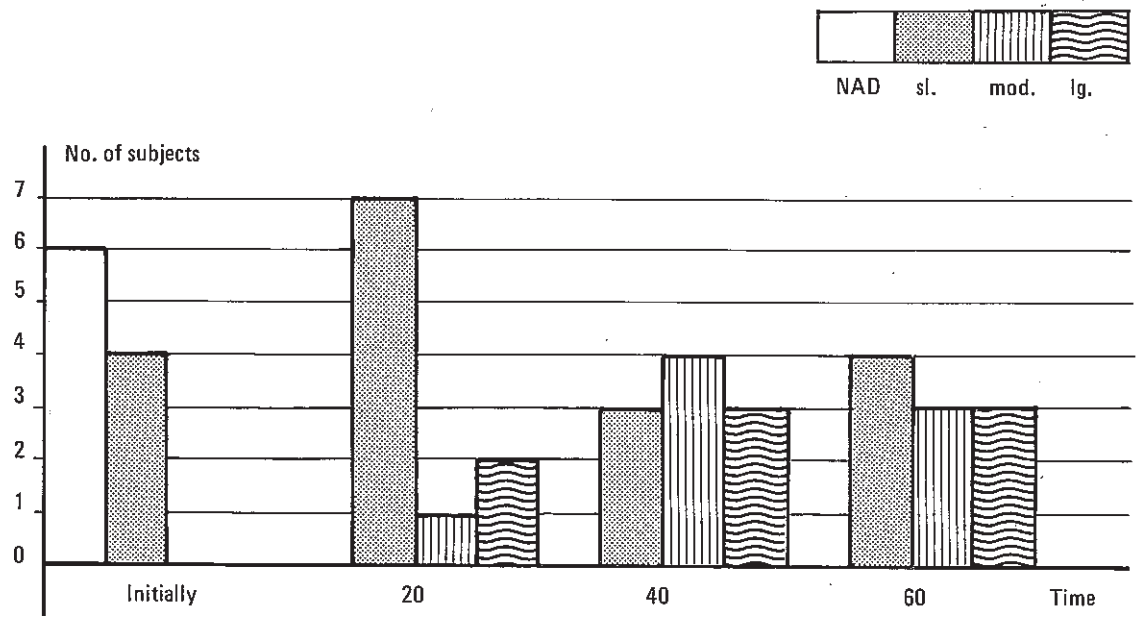

FIG 6: Ocular Movement Changes

All subjects showed varying degrees of inferior oblique overaction and associated 'V' pattern.
One subject developed a superior oblique underaction associated with the above.
Six subjects developed an intermittent divergent squint elevation.

DISCUSSION

The results of this assessment confirm previous reports mentioned, that following alcohol ingestion there is a tendency for near deviations to become more exophoric and distance deviations to become more esophoric.

It is interesting to note that the peak mean BAC was 0.0628%, marginally higher than the legal limit for this state, and the presence of abnormalities was just as evident here as in those studies where mean BAC were as high as 0.08% to 0.11%. Although the mechanism here is not clearly understood, Fender[14] says "the muscles that move the visual axis from side to side are quite sensitive and capable of precise movement" in comparison to the vertically acting muscles which act in a 23° plane rather than a vertical plane. Vertical phorias therefore tend to be more resistant than the horizontal phorias to fatigue (elicited by alcohol).

Powell[7] believes that the distance esophoria may be "due to a diminished muscle tonus and muscular control", whereas for near there is a "reduction of the convergence that is associated with accommodation due to either a decrease in muscular tone or an inefficiency of the associative centre," resulting in an exophoric shift for near.

A reduced convergence standard (Figure 4) may thus be related to a reduction of accommodative convergence and an associated reduction in muscle tonus, however proximal and fusional convergence would still be active, thus a constant reduction is evident over T40 to T60. No change was however noted in near visual acuity, suggesting that accommodation is intact. Obviously examination of accommodation under similar testing conditions is necessary before this can be assumed. Stereopsis showed no significant alteration since horizontally disparate similar images remain within fusable limits on the two retinae — the clear stimulus remains intact.

A significant reduction in visual acuity for distance (p 0.05) was established following

alcohol ingestion, which is inconsistent with previous studies. Two subjects complained prior to testing that they were experiencing blurred vision.

A marked change occurred when testing ocular movements. All subjects developed some degree of inferior oblique overaction from slight unilateral overaction to marked bilateral overaction with associated "V' exo pattern, which in four subjects became decompensated on elevation. These four subjects experienced heteronymous diplopia in dextro elevation, elevation and laevo elevation. Two of these subjects developed manifest deviations on elevation at T20, one at T40 and one at T60, all of which remained throughout the period of testing. In three of these cases an intermittent alternating divergent squint was evident on elevation without dissociation and in one case following dissociation. In only one instance was there an associated unilateral superior oblique underaction which became an intermittent divergent squint on elevation.

It is interesting to note that two other subjects developed end point nystagmus at T20 and T40 respectively. Howells[11] states that a minimum of 50 ml of ethyl alcohol is required to induce nystagmus, itself accentuated by changing directions of gaze and positions of the head. All six subjects mentioned thus far experienced trouble maintaining steady fixation and refixation, one of which consistently overshot refixation on depression and in the primary position over T40 to T60.

Two of the ten subjects tested showed unequal pupil reactions (direct and consensual) to light, one eye being more sluggish than the other. One subject from T40 to T60 experienced rapid blinking which increased on convergence.

Wilkinson, Kime and Purnell[2] stated that "alcohol affects cerebral function earlier and to a greater extent than mid-brain and brainstem function," to explain impairments in smooth pursuit and saccadic movements after alcohol, in contrast to normal doll's head movements. Interrupted cortical control over the extra ocular muscles possibly induces a tendency to deviate towards the anatomical position of rest, thus inducing divergence on elevation. Impairment to both smooth pursuit and saccadic movements explains difficulties of fixation and refixation whereas decompensation in the primary position and in other directions of gaze can be expected with increasing doses of alcohol.

Further studies on the effect of alcohol could be carried out firstly to examine the effects of alcohol on visual fields, dark adaptation and accommodation, and secondly a follow up of this study to examine increasing doses of alcohol and the levels at which subsequent changes become significant.

CONCLUSION

It is clear from this study that blood alcohol concentrations as low as 0.05% (the legal limit in NSW) elicit rather dramatic changes in the visual and ocular motor systems. This can be related to the performance of certain ocular motor skills, such as driving, in which hand-eye coordination may be affected. The respective shifts in distance and near deviations will alter judgement perceptions, i.e. esophorias tend to overestimate distances whereas exophorias underestimate.

Ramifications of this alone, not to mention the effects of other visual and ocular motor disturbances discussed, extend to areas of driving, water sports and any situation involving machinery such as a factory production line or a fork lift driver etc. Combine this with the proven impairment of cognitive performance[12] following alcohol ingestion and it can be seen that alcohol is a drug providing limitations to daily activity yet one which encourages such activity beyond safe limits.

ACKNOWLEDGEMENTS

My thanks to Professor Graham Starmer for his invaluable assistance, time and guidance, to Dr Elizabeth Post, Reg Mitchell and Elaine Cornell for their guidance and to Cathie Searle and Elizabeth Jones for their assistance in the laboratory.

References

1. Berry MS, Pentreath VW. Psychopharmacology of alcohol. The neurophysiology of alcohol. New York: Merton Sandler, 1980; 44.

2. Wilkinson IMS, Kime R, Purnell M. Alcohol and human eye movement. Brain 1974; 97: 785-792.
3. Cogan DG. Neurology of the ocular muscles. 2nd ed. Springfield, Illinois.
4. Ogle KN *et al.* Oculomotor imbalance in binocular vision and fixation disparity. Philadelphia: Lea and Febiger, 1967; 216.
5. McNamee JE, Piggins D, Tong J. Confirmation of the influence of alcohol on heterophoria using a vision screener. Am J Optom Physiol Optics 1981; 58 (9): 761-765.
6. Reynolds DC. A visual profile of the alcoholic driver. Am J Optom Physiol Optics 1979; 56 (4): 241-251.
7. Powell WH Jr. Ocular manifestations of alcohol and a consideration of individual variations in 7 cases studied. J Aviat Med 1938; 9: 97-103.
8. King AR. Tunnel vision. Quart J Stud Alcohol 1943-4; 4: 362-367.
9. Colson ZW. The effect of alcohol on vision. JAMA 1940; 115: 1525-1527.
10. Fender DH. Control mechanisms of the eye. Sci Am 1964; 211: 24-33.
11. Howells DE. Nystagmus as a physical sign in alcoholic intoxication. Brit Med J 1956; 1: 1405-1406.
12. Flom MC, Brown B, Adams AJ, Jones RT. Alcohol and marijuana effects on ocular tracking. Am J Optom Physiol Optics 1977; 53 (12): 764-773.