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ALCOHOL AND VISUAL FUNCTION — AN OVERVIEW

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Abstract

The effects of alcohol on complex hand-eye co-ordination are well known. Research on the ability of alcohol to degrade performance of the visual system, while not extensive, nevertheless allows for critical analysis. Review of this literature indicates that the ocular motor components of visual function are consistently and dose-dependently influenced by alcohol. There is some evidence of impairment of visual acuity and visual field, however the data with respect to the levels at which the deficit is apparent are not clear-cut. There is a need to specify functional implications on tasks requiring hand-eye co-ordination.

Key words: *Vision, ocular motor function, impairment.*

Alcohol is commonly known to affect cognitive and motor performance. Intoxication, even at moderate levels, can impair the ability of an affected person to perform both skilled hand-eye co-ordination tasks such as driving, piloting a plane or operating machinery, and simple daily tasks. The relative contributions of impairment in the perceptual and motor systems to alcohol-induced performance deficits is unknown. In the last 60 years there have been a number of studies of the susceptibility to alcohol of both the sensory and fine motor aspects of visual function. This paper summarises the literature in relation to changes in visual ability at various blood alcohol levels (BALs) and considers the functional implications of these changes to the visual system.

Alcohol is a small water-soluble molecule that penetrates cell membranes at the same rate as water. When administered orally, alcohol is rapidly absorbed into the circulation by diffusion across the gastric and intestinal mucosa.[1] Being a small, readily absorbed molecule that easily crosses membranes, means that alcohol has the potential to and does affect a wide variety of physiological systems.[2] The major site of action of alcohol is the central nervous system (CNS)[2] where clear effects are apparent in those structures that are involved in highly integrated functions such as the reticular activating system.[3] Starmer[4] argued that, broadly, the effects of alcohol can be:

"conceptualised as involving alterations of the afferent input from the sense organs and/or changes in the CNS, which confer a potential for disruption of the analysis of sensory

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information and the control of intricate movement patterns" (pp103-104).

Many types of tasks have been used to measure the effect of alcohol on cognitive and psychomotor performance. The common finding of these studies has been that there is significant and dose-dependent impairment of performance although differences exist between tasks as to the extent of the impairment.[2,4-7]

Published studies on the influence of alcohol on the visual system commenced around the late 1930s and early 1940s. In one study, copious amounts of spirits were consumed in the relaxed setting of a cocktail party and participants were tested for a variety of changes in their visual function over the course of the evening.[8] Fortunately, more recent studies have adopted more rigorous approaches to experimental design, subject selection and statistical analysis.

Vision and Alcohol

Static visual acuity has been found to be resistant to alcohol, even when low contrast stimuli have been used. No conclusive impairment of static visual acuity has been obtained at low BALs.[9] Some impairment of static vision is found at moderate BALs.[10-13] However a number of researchers have found no change even at moderate and high BALs.[14,15] Only one study has investigated dynamic visual acuity, the impairment of which is arguably more important in driving. Honegger, Kampschulte and Klein[16] used a visual tracking device in which a single letter was projected on a screen and then rotated in a circle at selected speeds. In this study it was shown that dynamic visual acuity is significantly reduced while alcohol levels are rising and begins to improve once BAL starts to decrease. Subjects with low BALs and no reported subjective feelings of intoxication, had significantly impaired dynamic visual acuity.

Restriction of the visual field could be considered to present a major hazard to driving. Except at relatively high doses of alcohol (0.10%) there does not appear to be any appreciable reduction in the extent of the lateral visual field.[8,15,17,18] Interest has moved to visual field examination tasks that require divided attention, that is time-sharing of the fovea and an extra foveal task more or less simultaneously and the processing of information. Von Wright and Mikkonen[19] found significant performance deficits at a BAL of approximately 0.05% when tracking and visual recognition tasks were combined. Moskowitz et al[14] examined the detection of peripheral stimuli. Alcohol was found to impair the central processing of peripheral visual information when processing of that information conflicted with processing of information from other sources. The deficit appears to be in the ability to divide attention and process information. It was concluded that the effect of alcohol on peripheral vision was a function of the information load on central vision.

Dark adaptation, in terms of detection of low contrast targets, is not impaired at low or moderate BALs.[14,20] Reduction of glare resistance has been cited as a potential driving hazard especially at night, although no studies provide strong evidence for a consistent influence of alcohol upon glare tolerance, resistance or receovery.[10,12]

Critical flicker fusion refers to the transition point at which a rapidly flickering light source is first perceived as continuous. This function has been used as an index of the temporal resolution of the visual system as well as an indicator of central nervous system function. The literature offers differing conclusions concerning the effects of moderate levels of alcohol. The results indicate impairment at moderate to high BALs,[21,22] but below these levels the findings are inconsistent. The concern here is that in the general population the range of normal results has not been clearly defined.

The literature is inconsistent on the impact of alcohol on accommodation, with one report of a decreased stimulus AC/A ratio[23] and controversy regarding the change to accommodative amplitude.[15,24]

Ocular Motor Function and Alcohol

The literature is consistent in reporting that the effects of low doses of alcohol are apparently capable of producing marked decrements in ocular motor function. Numerous studies have reported a significant esophoric shift in distance measurement and an exophoric shift for near measurement.[8,11,13-15,20,25-28] Change at distance is usually greater than at near and can be seen even with low BALs. Vertical heterophoria is not induced or altered.[11,14,27]

Deterioration of motor and sensory fusional ability results from the ingestion of alcohol, and this is manifested as a loss of abduction power.[11,14,23,26,28] The decrement of the convergence near point is associated with a reduction in the fusion ability as reported by several studies.[13,15,23,28]

Defects in binocular co-ordination could be expected to cause impairment of depth perception Wist et al[29] reported that moderate BALs were associated with a significant increase in fixation disparity, but stereoacuity was unaffected at this level. Hill and Toffolon[15] confirmed this finding showing no significant change in stereoacuity in their study.

There are few reports in the literature regarding the influence of alcohol on the saccadic and smooth pursuit eye movement systems prior to 1974. A typical saccade is initiated approximately 180 milliseconds after the target stimulus is activated and peak velocity is rapidly achieved. Normal subjects can miss the target by undershooting or overshooting which necessitates a second corrective saccade. Peak velocity increases with the amplitude of the movement, reaching a maximum at saccades of approximately 30 degrees. These properties make saccades the fastest and best controlled movements of which the body is capable.

A number of recent studies have found the tendency for saccadic peak velocity for saccades of 20 degree amplitude to be reduced by between 7 and 25% at BALs of 0.05% and above.[28,30-33] Methodological and instrumentation limitations have made definitive measurement of changes in latency difficult, however Katoh[33] has reported an increase in the latency of saccades of between 8 and 17%. According to Wilkinson et al,[30] smooth eye movements become jerky after alcohol with catch up saccades being required to continue the pursuit eye movements.

The presence of nystagmus after alcohol ingestion is well known and in fact forms the basis of a roadside sobriety testing device which has been recently piloted in a number of states in the USA.[34] Howells[35] examined alcohol-induced nystagmus and reported that all subjects demonstrated nystagmus after 50 mL of absolute alcohol but at varying durations post ingestion. Seedorff[26] accounted for nystagmus in terms of the action of ethanol on the vestibular system and cerebellum.

DISCUSSION

From this review of the literature it can be seen that the visual and ocular functions most consistently and significantly influenced are specific components of the ocular motor system. There is a change to the static deviation with an increase in esophoria at distance, and increase in exophoria at near. Motor fusional reserves and the ability to converge at near range are impaired. In addition, there are reported changes in saccadic latency and velocity and a reduction in ability to conduct smooth pursuit eye movements.

It can be argued on the basis of these results that the reported nystagmus is either a direct result of decrements to the saccadic and smooth pursuit systems, or that the measured and reported changes in these functions of eye movement are simply manifestations of the nystagmus. Whichever it is, it is not possible simply on the basis of these results to specify the affected pathway for eye movement, nor is it possible to determine the functional effect on motor behaviour without additional performance testing. It is reasonable to assume that the oscillopsia known to be produced by acquired nystagmus would almost certainly lead to reduced visually driven motor performance, but there is little evidence in the literature.

The ocular motor system exists to allow shifts in visual direction and to maintain comfortable binocular single vision and smooth conjugate eye movement control. Whether a change in the heterophoria position will alter judgement perceptions as Wilson and Mitchell[13] have suggested is unclear given the available data. The slowing of a 20 degree horizontal saccade to a peripheral stimulus may mean the difference between a quick response to danger or not, but is yet to be proven. The point at which the alcohol dose dependent decrement in the binocular system will mean an impairment in binocular performance is also yet to be established.

The other issues that need to be addressed are the complex perceptual and cognitive aspects of visuomotor activity before any meaningful decisions regarding the functional implications of ocular motor change can be determined. It would appear that the studies conducted by Moskowitz et al[14] requiring a divided attention response to visual field testing move closer to incorporating visuomotor aspects of function with perceptual responses also. Complex tasks such as driving place demands not only on the visual act but on the perceptual ability of the driver who in turn must produce a set of appropriate motor responses and behaviours. To extrapolate a direct result on the ability to drive or produce any other set of behaviours from the available data on visual function is clearly inappropriate and methodologically unsound. Many of the studies do attempt to do this even if only by inference.

CONCLUSION

The functional implications of the observed changes in the visual system as a result of alcohol ingestion have yet to be established. Hand-eye co-ordination tasks involve the interaction of a number of physical and cognitive systems so isolating the influence of visual function on these tasks would be very difficult. Without further studies which address the complex inter-relationships between afferent and efferent systems it can only be hypothesised that these observed changes will influence the overall performance decrement of the intoxicated person.

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